United States
Department of
Agriculture

Forest Service

Forest Pest
Management

Davis, CA

THIRD REPORT

National Steering Committee for Management of Vegetation on Forest and Range Lands

FPM 93-6
January 1993

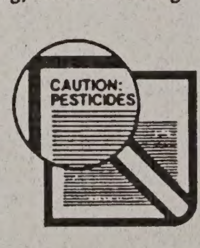
Pesticides used improperly can be injurious to human beings, animals, and plants. Follow the directions and heed all precautions on labels. Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides where there is danger of drift when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment, if specified on the label.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U.S Environmental Protection Agency, consult your local forest pathologist, county agriculture agent, or State extension specialist to be sure the intended use is still registered.



FPM 93-6
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THIRD REPORT

National Steering Committee for
Management of Vegetation on
Forest and Range Lands

Compiled by:

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Douglas L. Parker

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Forest Pest Management
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CONTENTS

I. INTRODUCTION

The third meeting of the National Steering Committee for Management of Vegetation on Forest and Range Lands met at Davis, CA, December 1-2, 1992.

A. Committee Members Attending

Phil Aune	USFS/PSW (Redding, CA)
Jack Barry	WO/FPM (Davis, CA)
Garth Baxter	R-4/FPM (Ogden, UT)
Jim Brown	R-8/FPM (Atlanta, GA)
Bob Campbell	Forestry Canada (Sault Ste. Marie, ON)
Jesus A. Cota	WO/FPM (Washington, DC)
George Ice	NCASI (Corvallis, OR)
Charlie McMahon	SO (Auburn, AL)
Ed Monnig	R-1/FPM (Missoula, MT)
Doug Parker	WO/FPM (Washington, DC)
Mike Rutty	Stanislaus NF (Sonora,CA)
Dave Thomas	Eldorado NF (Placerville, CA)

Complete addresses are provided in **Appendix D**.

B. Proposal of a Committee Charter

Committee Title: National Steering Committee for Managing Vegetation on Forest and Range Lands

Committee Purpose: The purpose of this committee is to provide recommendations on an annual basis to the USDA Forest Service, Washington Office staffs that support safe, effective, economical, and environmentally sound use of pesticides.

Committee Scope: The scope of this committee shall include herbicide-use management as it relates to environmental impact and documentation, herbicide environmental fate, risk assessment, herbicide application technology, training, information databases, and information and technology transfer.

Proposed Committee Representation:

- USDA Forest Service

  Forest Environmental Research Staff

  Forest Management Research
  National Forest System - Timber Management, Range Management, Watershed and Air Management, Wildlife & Fisheries

  Forest Pest Management

- Forest Industry

- State Forestry

- Utility Industry

Funding Sources: Projects, studies, and tests recommended by this committee and approved by Washington Office should be funded by the Staff or/and manager receiving direct benefits.

C. Committee Member Reports

Committee member reports are enclosed in **(Appendix A)**.

II. RECOMMENDATIONS/ACTIONS

A. Recommendations

Recommendations are categorized by high, medium and low priority.

<u>High Priority</u>

1. <u>Committee Charter</u>

   Approve committee charter as outlined in Paragraph I.B.

2. <u>National Policy</u>

   Reaffirm National Forest Service policy and support of herbicides as a tool in ecosystem management.

3. <u>FPM's Herbicide Role</u>

   Clarify WO/FPM's role in herbicide-use management. Although this is addressed in FSH 2109.14 there appears to be confusion on this point.

4. <u>Ecosystem Management</u>

   Evaluate role of herbicides in ecosystem management.

5. <u>Risk Communications</u>

   Develop a nationally coordinated effort on how to communicate risk to the public and employees.

6. <u>Technology Development Program</u>

   Include herbicide application technology in the WO/FPM technology development program with funding contributions from benefiting staffs e.g. Range, Timber, Wildlife, and Recreation.

7. <u>Herbicide Monitoring Data Base</u>

   Develop a database to monitor efficacy and environmental impact of herbicides. Initial step will be to identify existing efforts and to develop criteria for the database.

8. <u>Human Exposure Studies</u>

   Review and document the literature on human exposure data to identify data gaps and prepare bibliography and recommendations to address data gaps.

9. Partnerships with Canada

Establish one-on-one Canada/USA partnerships to work on herbicide application, efficacy, and safety issues.

Medium Priority

1. Herbicide-Use Training

Determine and provide national level herbicide-use training.

2. NAPIAP

Distribute results of NAPIAP studies on herbicides fate and toxicology. Encourage peer review publications.

3. Networking

Develop mechanisms for information flow among Regions and Stations and among Regions and WO. Examples are NAPIAP summaries to Regions, develop and maintain target mailing lists and "Timely Tips".

4. International Role

Determine policy role of Forest Service in advising international partners in use of herbicides with consideration to science vs politics, environmental concerns, economics, reforestation, habitat restoration, etc.

5. Long-Term Monitoring

Establish long-term studies to monitor impact of herbicides on biodiversity and efficacy.

Low Priority

1. NFS vs Private Use of Herbicides

Prepare a white paper on land management objectives that reviews the likely reasons for conflict among adjoining landowners over use of herbicides.

2. Ecological Risk Assessment

Evaluate need to prepare ecological risk assessments in the future.

B. Actions

Two sub-committees were appointed to follow-up on issues discussed during the meeting.

1. **Vegetation Management Monitoring Database Sub-Committee**

   The sub-committee will address the need for a database of environmental and efficacy data generated by herbicide projects. Operational and other projects provide opportunities to capture and archive data that are useful for a number of purposes including environmental documentation and technology development. For data to be meaningful, therefore, its generation, collection, and storage needs a protocol and consistency. The initial charge of the sub-committee is to outline an approach to establishing a database that includes criterion to be followed and to be reported by project people who are willing to participate.

2. **Worker Exposure Sub-Committee**

   The sub-committee will review the literature and produce an annotated bibliography, identify worker exposure data gaps, and draft recommendations for committee review. This assignment should be completed by December 1993.

III. SUMMARY

The National Steering Committee for Managing Vegetation on Forest and Range Lands met at Davis, California on December 1-2, 1992. The committee developed several recommendations, and reviewed and discussed accomplishments related to but not necessarily a result of the committees 1989 and 1990 recommendations. The committee identified and prioritized several issues and have submitted recommendations to address these issues. Two sub-committees were established to follow-up on issues of human exposure to herbicides and to herbicide monitoring and efficacy databases. The committee recommends that its charter be revised to limiting the committee's activities to herbicide-use on forest and range lands. Currently the charter includes all methods of managing vegetation.

APPENDIX A

Phil Aune
PSW

Phil Aune
4/91

R-5/PSW Vegetation Management Study Plots

Study Area[1]	Conifer Spp.[2]	Target Spp.	Treatment	Area/Type
National Administrative				
Klamath NF Salmon River RD	DF	deerbrush grasses	control crop tree release directed spray directed spray	 2,3,4,& 6' radius 2,4-D[3], 3' radius 2,4-D, entire plot
Shasta-Trinity NF Big Bar RD	DF	deerbrush madrone tanoak	control cut and spray crop tree release directed spray	 Garlon 3A 5' radius 2,4-D, Garlon 4, and 2,4-D plus Garlon 4
Six Rivers NF Gasquet RD	DF	manzanita deerbrush tanoak	control directed spray crop tree release cut and spray	 2,4-D, Garlon 4, and 2,4-D plus Garlon 4 5' radius Garlon 3A
Six Rivers NF Gasquet RD	DF	snowbrush manzanita tanoak	control crop tree release directed spray cut and spray	 5' radius 2,4-D, Garlon 4, and 2,4-D plus Garlon 4 Garlon 3A
Lassen NF Hat Creek RD	PP	manzanita chinkapin snowbrush	control grub simulated aerial manual crop tree release chain saw crop tree release	 100% 2,4-D, Velpar 4' radius 4' radius
Shasta-Trinity NF McCloud RD	PP	manzanita chinkapin snowbrush grasses	control crop tree release simulated aerial directed spray	 2, 4, & 6' radius 2,4-D Velpar
Tahoe NF Foresthill RD	PP SP DF	deerbrush	control grub grub simulated aerial	 100% 5' radius 2,4-D, Velpar

Tahoe NF Downieville RD	PP DF SP	deerbrush	control simulated aerial directed spray cut brush	 2,4-D 2,4-D, 3' & 5' radius 100%
Plumas NF Quincy RD	PP DF	deerbrush manzanita chinkapin	control simulated aerial grub crop tree release simulated aerial	 2,4-D, Velpar 100% 2' and 4'radius Roundup
Plumas NF Quincy RD	PP JP	snowbrush manzanita chinkapin	control Hydro-ax Hydro-ax	 2,4-D
Tahoe NF Nevada City RD	PP	manzanita whitethorn bittercherry	control Trac-mac Trac-mac	 2,4-D
Tahoe NF Downieville RD	PP DF	deerbrush	seedlings seedlings, brush seedlings, brush, deer seedlings, brush, deer and sheep	
Modoc NF Big Valley RD	PP	grass	seedlings seedlings, grass heavy grazing acceptable grazing	Velpar
Eldorado NF Amador RD	PP	bearclover	control directed spray simulated aerial simulated aerial simulated aerial	 Roundup Velpar L Escort Arsenal
Cooperative Release				
Klamath NF Oak Knoll RD	PP	live oak	control cut and spray directed spray directed spray crop tree release	 Garlon 3A Garlon 4 Velpar 100%
Klamath NF Salmon River RD	PP	deerbrush	control grub 1 time grub 2 times crop tree release	 100% 100% 5' radius

Klamath NF	DF	tanoak	control	
Happy Camp RD		madrone	cut and spray	Tordon 101
			cut and spray	Garlon 3A
			cut,spray, and burn	Tordon 101
			cut,spray, and burn	Garlon 3A
			cut,burn, and directed spray	Garlon 4
Six Rivers NF	DF	tanoak	control	
Mad River RD			crop tree release	5' radius
Plumas NF	DF	tanoak	control	
Oroville RD			collars	3' radius
			collars	5' radius
Plumas NF	DF	tanoak	control	
Oroville RD			basal	Alumagel
Plumas NF	JP	snowbrush	brush, seedlings, sheep	
Milford RD			seedlings, brush	
			seedlings	4 ft. radius
			seedlings	Velpar
Shasta-Trinity NF	PP	forbs	control	
Yolla-Bolla RD		grasses	grub, 1 time	2' radius
			grub, 3 times	2' radius
			grub, 1 time	5' radius
			grub, 3 times	5' radius
			collars	1.5' radius
Eldorado NF	PP	whitethorn	collars,tar paper	20" radius
Amador RD		lupine	collars,felt	20" radius
			collars,Terramat	20" radius
			collars,Pacific weave	20" radius
			collars,Horto paper	20" radius
			collars,black plastic	20" radius
			control	
			directed spray	Velpar

Sequoia NF Hot Springs RD	PP	manzanita	control directed spray collars, thick collars, thin collars, sandwich	 Velpar 5' radius 5' radius 2' radius
Latour State Forest	PP	chinkapin	simulated aerial simulated aerial simulated aerial control	Velpar Garlon 4 Escort
Plumas NF La Porte RD	PP	deerbrush (older)	seedlings, cattle seedlings, no cattle	
BLM Arcata RA	DF	tanoak chinkapin	crop tree release yrs 1-10 croptree release yrs 0,1,2,5,10 croptree release yrs 0,5,10 control	entire plot entire plot entire plot
BLM Arcata RA	DF	grasses forbs	polypropylene mat polypropylene mat scalp control	5' radius 1' radius 1' radius
Stanislaus NF Mi Wok RD	PP	bearclover seeded grass	simulated aerial simulated aerial simulated aerial control	Velpar(~~ULW~~) 10 G Garlon 4 Roundup
Stanislaus NF Mi Wok RD	PP	bearclover natural grass	simulated aerial simulated aerial simulated aerial	Velpar(~~ULW~~) 2-5G Garlon 4 Roundup
Boggs Mtn. State Forest	PP	natural vegetation	openings from 1/4 to 1 3/4 acres	
Lassen NF Hat Creek RD	PP	manzanita bitter cherry snowbrush	Trac Mac Trac Mac Trac Mac	June 15 August 15 October 15
Eldorado NF Georgetown RD	PP	manzanita	nursery run wind pollinated control pollinated	free to grow and with weeds in each genetic class

Tahoe NF Foresthill RD	PP	manzanita natural and seeded grass	seedlings, cattle seedlings, no cattle	
			simulated aerial	Velpar L
			seedlings, grass seedlings, no grass	

Timing of Release

Shasta-Trinity NF Mt. Shasta RD	PP	manzanita snowbrush grasses chinkapin	control crop tree release crop tree release	 Free to grow 1st 3 years Free to grow 2nd 3 years
Klamath NF Goosenest RD	PP	manzanita snowbrush chinkapin	control crop tree release crop tree release	 Free to grow 1st 3 years Free to grow 2nd 3 years
Klamath NF Salmon River RD	DF	deerbrush forbs	control crop tree release crop tree release	 Free to grow 1st 3 years Free to grow 2nd 3 years
Plumas NF Quincy RD	JP	manzanita squawcarpet deerbrush	control crop tree release crop tree release	 Free to grow 1st 3 years Free to grow 2nd 3 years
Santa Fe-Pacific 2 Stephens Pass	WF RF	manzanita snowbrush grasses	control crop tree release crop tree release free to grow	 Free to grow 1st 3 years Free to grow 2nd 3 years Study life

40 study areas

December 1, 1992

LIST OF PUBLICATIONS

National Administrative Study

1. McDonald, Philip M. 1983. Weeds in conifer plantations of northeastern California--management implications. In: Proceedings of a symposium on the management of the Eastside Pine Type in northeastern California. Susanville, June 15-17, 1982. p. 70-78.

2. Fiddler, Gary O., and Philip M. McDonald. 1984. Alternatives to herbicides in vegetation management: a study. In: Proceedings, 5th Annual Forest Vegetation Management Conference, Nov. 2-3, 1983. Sacramento, CA. p. 115-126.

3. McDonald, Philip M., and Gary O. Fiddler. 1986. Weed treatment strategies to control losses in ponderosa pine plantations. In: Proceedings of a workshop on forest pest management in Southwest Oregon. Grants. Pass, OR. August 19-20, 1985. p. 47-53.

4. McDonald, Philip M. 1986. Grasses in young conifer plantations--hindrance and help. Northwest Sci. 60(4): 271-278.

5. McDonald, Philip M., and Gary O. Fiddler. 1986. Release of Douglas-fir seedlings: growth and treatment costs. USDA Forest Serv. Res. Paper PSW-182, 9 p.

6. Fiddler, Gary O., and Philip M. McDonald. 1987. Alternative treatments for releasing conifer seedlings: a study update. In: Proceedings of the Eighth Annual Forest Vegetation Management Conference. Nov. 5-6, 1986, p. 64-69. Sacramento, CA.

7. McDonald, Philip M., and Gary O. Fiddler. 1987. Growth and treatment costs after release of Douglas-fir seedlings on the Klamath National Forest. In: Proceedings of the Eighth Annual Forest Vegetation Management Conference. Nov. 5-6, 1986, p. 56-63. Sacramento, CA.

8. McDonald, Philip M., and Gary O. Fiddler. 1988. Release of young pines by sheep--no effect after five years. In: Proceedings of the Ninth Annual Forest Vegetation Management Conference. Nov. 3-5, 1987, p. 168-174. Redding, CA.

9. Ratliff, Raymond D., and Philip M. McDonald. 1988. Postfire grass and legume seeding: what to seed and potential impacts on reforestation. In: Proceedings of the Ninth Annual Forest Vegetation Management Conference. Nov. 3-5, 1987, p. 111-123. Redding, CA.

10. McDonald, Philip M., Gary O. Fiddler, and William H. Smith. 1989. Mulches and manual release fail to enhance Douglas-fir seedling survival and growth. In: Proceedings of the Tenth Annual Forest Vegetation Management Conference. Nov. 1-3, 1988, p. 140-153. Eureka, CA.

11. McDonald, Philip M., Gary O. Fiddler, Richard A. Tucker, and Andrew Colaninno. 1989. Manual release in an "old" Douglas-fir plantation increases diameter growth. USDA Forest Serv. Res. Note PSW-405. 3 p.

12. McDonald, Philip M., and Gary O. Fiddler. 1989. Competing vegetation in ponderosa pine plantations: ecology and control. USDA Forest Serv. Gen. Tech. Rep. PSW-113. 26 p.

13. McDonald, Philip M., and Gary O. Fiddler. 1990. Ponderosa pine seedlings and competing vegetation: ecology, growth, and cost. USDA Forest Serv. Res. Paper PSW-199. 10 p.

14. Fiddler, Gary O., and Philip M. McDonald. 1990. Manual release contracting: production rates, costs, and future. Western Journal of Applied Forestry 5(3): 83-85.

15. McDonald, Philip M., and Ole T. Helgerson 1991. Mulches aid in regenerating California and Oregon forests: past, present, and future. USDA Forest Serv. Gen. Tech. Rep. PSW-123. 19 p.

16. Fiddler, Gary O., and Philip M. McDonald. 1991. Integrated vegetation management in California--advances and future. The Forestry Chronicle 67(5): 528-531.

17. McDonald, Philip M., and Gary O. Fiddler. 1991. Vegetation management in young conifer plantations in California. In: Proc. 44th Annual Meeting, Southern Weed Science Society. San Antonio, Texas. January 14-16, 1991. 44: 257-264.

18. McDonald, Philip M., and Gary O. Fiddler. 1991. Grazing with sheep: effect on pine seedlings, shrubs, forbs, and grasses. In: Proc. 2nd Agroforestry Conference in North America, Springfield, Missouri. August 18-21, 1991. p. 221-231.

19. McDonald, Philip M., and Steven R. Radosevich. 1992. Chapter 4. General principles of forest vegetation management. In: Black, Hugh C. tech ed. Silvicultural Approaches to Animal Damage Mangement in Pacific Northwest Forests. USDA Forest Serv. Gen. Tech. Rept. PNW-GTR-287. p. 67-91.

20. McDonald, Philip M., Carl N. Skinner, and Gary O. Fiddler. 1992. Ponderosa pine needle length--an early indicator of release treatment effectiveness. Canad. J. For. Res. 22(5): 761-764.

21. Fiddler, Gary O., and Philip M. McDonald, and Carl R. Chapman. 1992. Releasing young conifers with herbicides: fast and effective. In: Proc. 45th Annual Meeting, Southern Weed Science Society. Little Rock, Arkansas. January 20-22. 45: 209-218.

22. McDonald, Philip M., Gary O. Fiddler, and W. Thomas Henry. 1993. Growth of ponderosa pine seedlings enhanced by large mulches and manual release. (To: New Forests).

23. McDonald, Philip M., Celeste S. Simpson, and Gary O. Fiddler. 1993. Ponderosa pine seedlings, shrubs and ferns: growth response with and without treatment. (To: West. J. Appl. For.).

24. McDonald, Philip M., Gary O. Fiddler, and Jay H. Kitzmiller. 1993. Genetically improved ponderosa pine seedlings outgrow nursery-run seedlings with and without competition--early findings. (To: West. J. Appl. For.).

25. McDonald, Philip M., and Gary O. Fiddler. 1993. Feasibility of alternatives to herbicides in young conifer plantations. (To: Canad. J. For. Res.).

26. McDonald, Philip M., and Gary O. Fiddler. 1993. Vegetative trends in a young confer plantation after ten years of grazing by sheep. USDA Forest Serv. Res. Paper PSW-000. 00 p.

27. McDonald, Philip M., and Gary O. Fiddler. 1993. Forest vegetation management in California in the 1990's: a time of change. In: Proc. 46th Annual Meeting, Southern Weed Science Society. Charlotte, NC. January 17-19. 46: 000-000.

Jack Barry
WO/FPM

FPM WESTERN DIRECTOR'S MEETING
September 28, 1992

SUBJECT: VEGETATION MANAGEMENT STEERING COMMITTEE

DISCUSSION POINTS:

- Committee was established by the Chief in 1988 to identify field and pilot testing needs for aerial application of herbicides.
- Committee met in January 1989 and March 1990.
- Committee broadened its charter in 1990 to include all methods of managing vegetation and changed it's name to "National Steering Committee for Managing Vegetation on Forest and Range Lands."
- Third meeting scheduled for September 1991 was cancelled due to Regional travel restrictions and rescheduled.
- There is lack of a WO coordination point for follow-up of committee recommendations. Need a staff to adopt vegetation management.
- Recommendations involved Research, NFC, and S&PF.
- Next committee meeting is December 1-2, 1992 at Davis, CA.
- Is this committee needed - yes by the Forest Service, but to whom does it report?
- Biological control of weeds is very promising. Who in the Forest Service other than FPM and FIDR should be involved with insects?
- Who has responsibility for technology development and evaluation of ULV and UULV aerial application of dry herbicides?

ADDED INPUT FROM DISCUSSION:

DECISION/RECOMMENDATION:

• Space suggested someone from WO-Range & TM on committee.
• Which weeds are priority?

ACTION:

What:
Who:
When:

no action other than above was discussed

---

1. First Report A Report by the National Steering Committee for aerial Application of Pesticides - Vegetation Management, April 6, 1989.

2. Second Report National Steering Committee for Application of Pesticides - Vegetation Management, May 11, 1990.

Field worker injury in vegetation management programs

Information taken from Ontario Workmen's Compensation reports between 1980 and 1989 indicates that there are more reportable injuries associated with manual tending programs than with aerial or ground application of herbicides. Information from the reports showed that reportable injuries occurred 14 times more frequently on manual tending programs than on aerial or ground herbicide tending programs. However, because far more area is treated with herbicide than manually, the figures are not directly comparable. By adjusting the figures so that they are compared on an equivalent number of ha treated, the ratio of injuries on manual tending programs vs. injuries on chemical programs comes out to 266:1 and the lost time due to injury ratio is in the order of 750:1.

If aerial and ground application figures are separated, the ratios come out as follows:

	Ratio of reportable injuries	Ratio of man days lost
ground vs. aerial	4:1	5:1
manual vs. ground	112:1	280:1
manual vs. aerial	420:1	1327:1

If the current vegetation management program in Ontario was replaced with a manual tending program, the cost would be about three times greater and there would be a greater chance of worker injury. This does not take into account the unknown health effects that pesticide use might have on forest workers sometime in the future. However there is evidence that shows that forest workers involved in the application of 2,4-D take exceptional care of themselves, and go to great lengths to avoid occupational exposure to the pesticide they are handling. This was substantiated by a consultant who surveyed 2,4-D users on behalf of the Ontario Ministry of the Environment.

It also does not take into account the improvement that would inevitably come about if manual tending became more commonplace and worker training was increased.

The most common injuries reported for workers performing manual tending were exactly as would be expected when working in cutovers: bee sting, twig in eye, and sprain.

• *Craig Howard*

FOREST PEST MANAGEMENT INSTITUTE

NEWSLETTER

Editor • K. B. Jamieson
Design • Victoria Mervyn

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[redacted]

Vol. 10(1) FPMI Summer 1992

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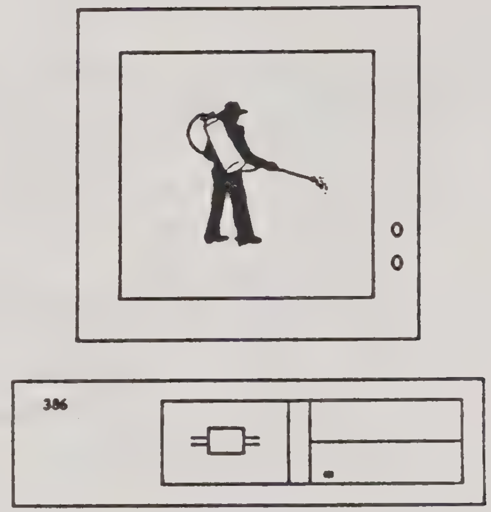
ChESS

Chemical Expert System for Silviculture



Version 1.1
September 1990

What is ChESS?

ChESS (Chemical Expert System for Silviculture) is a computer program that writes herbicide prescriptions and provides herbicide information for southern pine management. It is a decision support system which develops recommendations consistent with EPA (Environmental Protection Agency) regulations (herbicide labels) as of the date of release. It does not constitute an endorsement of commercial products nor does it exempt the user from any legal obligations under federal, state, or local statutes.

Purpose

The multitude of conditions that influence the efficacy, utility, and environmental safety of herbicides makes the process of prescription writing for herbicide application difficult, if not impossible, for an inexperienced person. Because of its complexity, and the substantial penalties for errors, most organizations relegate the task of prescription development to a few, recognized experts. ChESS was designed to improve the prescription writing process for herbicides used in the management of southern pine forests in two ways. First, ChESS was developed to raise the level of performance in prescription writing of the average graduate forester. And second, ChESS was designed to allow "local" (company, agency, organization) herbicide experts to update and adapt the decision making process to meet local needs and conditions.

Where did ChESS come from?

Version 1.1 of ChESS was developed over a two year period by researchers in the Department of Forestry and the Department of Computer Science at Virginia Polytechnic Institute and State University. Essential advice and expertise was derived from a distinguished panel of recognized experts from industry, state and federal forestry agencies, and university faculty from throughout the Southeast. As such, ChESS is a compromise of expertise that will perform well, given the average (nominal) conditions, but requires customization (by a local expert) to perform at, or near, the local expert's ability. The data used in the decision making process will also require periodic updates as new herbicides, regulations, labels, and application techniques are developed. However, it is the user's responsibility to ensure that the current version used conforms to all applicable regulations and requirements.

Who to contact for more information and technical assistance

Dr. Shepard M. Zedaker
Department of Forestry
Virginia Polytechnic Institute
and State University
Blacksburg, VA 24061
Phone: (703) 231-4855
Fax: (703) 231-3330

Hardware requirments

IBM PC or compatible:
- DOS 3.3 or above
- 80386 processor
- 5 Mb free fixed disk space
- 2 - 4 Mb system memory (2 minimum, 4 optimal)

VAX
- VMS version 5.0 or above
- MicroVAX II (.9 MVUPS) or above
- 5 Mb free fixed disk space
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- MV 15000 or above
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United States Department of Agriculture
Forest Service
Washington Office
2121 C Second Street
Davis, CA 95616

Reply To: 2150

Date: December 18, 1992

Subject: 2,4-D/Dog Cancer Study

To: Members, National Steering Committee for Management of Vegetation on Forest and Range Lands

Dr. Bob Campbell kindly followed-up on the discussion of a reported relationship of 2,4-D and cancer in dogs. This was the subject of a USDA Forest Service Pesticide Use Memorandum (No. 453) issued September 1991. The enclosed letter and its enclosures provide additional relevant information.

John W. Barry
JOHN W. BARRY
Chairperson

Enclosure

cc: J. Cota w/enclosure
V. Shannon w/enclosure
Z. Horakova w/enclosure

Forestry Canada
Forêts Canada

11 Dec 1992

Your file Votre référence

Our file Notre référence

Dr. John W. Barry
USDA Forest Service
2121C Second Street
Davis, CA
USA 95616

Dear Jack:

At the recent National Steering Committee for Managing Vegetation meeting, one member indicated that one reason why his region did not want to use 2,4-D was a recent study claiming a relationship between 2,4-D use on lawns and cancer in dogs. I suspect he was not aware that the conclusions of that study have been refuted. It is not surprising that flaws were found in the study in view of the fact that the claimed carcinogenic effect has not been detected in controlled laboratory studies with much higher and prolonged exposure than a dog could receive from treated turf (dislodgeable residues decrease rapidly with time as indicated in enclosed paper by Harris and Solomon). Nevertheless, I do realize that studies such as this, even when refuted, do make it more difficult for forest managers to use 2,4-D.

Yours truly,

Robert A. Campbell
Research Scientist

Encl. 2,4-D Dispatch May 1992
Harris & Solomon 1992

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2,4-Dispatch

MAY 1992

INDUSTRY TASK FORCE ON 2,4-D RESEARCH DATA Information Line: U.S. 1-800-345-5109 FAX 1-919-964-4559

No Link Found Between 2,4-D And Cancer In Dogs

EXECUTIVE SUMMARY: Review Panel Report on "Case-Control Study of Canine Malignant Lymphoma: Positive Association With Dog Owner's Use of 2,4-Dichlorophenoxyacetic Acid Herbicides"

Last September, the Journal of the National Cancer Institute published a study suggesting links between lawn care uses of the herbicide 2,4-D and malignant lymphoma in dogs. This study raised predictable concerns among lawn applicators and home owners.

In response to these concerns, the Industry Task Force on 2,4-D Research Data commissioned an independent panel of scientists to review the study and its conclusions. After careful review, the panel found that due to limitations in design, the study's data did not support an association between 2,4-D and malignant canine lymphoma.

Two primary reasons were given by the panel as to why the study was unable to show an association. First, the study was based on responses of dog owners, using a questionnaire that gave too little information about which dogs were exposed to 2,4-D and how much exposure they had. Second, the panel noted that the effect reported by the study was small, so that it may have been due to chance or might be linked to other factors in the dogs' environments.

The findings of the dog study review panel are summarized below. These findings are consistent with the weight of the evidence based on extensive scientific testing which has not found a link between animal cancers and 2,4-D. The complete text of the review is also available through the task force.

— The Editors

INTRODUCTION

In December 1991, an independent scientific review panel was convened by Drs. Ian Munro and George Carlo to evaluate critically the methodology and findings of the study by Hayes *et al.* entitled, "Case-control study of canine malignant lymphoma: Positive association with dog owner's use of 2,4-dichlorophenoxyacetic acid herbicides."[1] The Study was published in the Journal of the National Cancer Institute's September 4, 1991, issue. This independent peer review was supported by the Industry Task Force II on 2,4-D Research Data.

The scientific panel reviewed the published study, media releases that accompanied the public release of the study, and the interview instrument employed by the study investigators which was provided by the National Cancer Institute. A meeting of the panel took place during December 1991. The panel was charged with evaluating the degree to which the study by Hayes *et al* supported the hypothesis that 2,4-dichlorophenoxy acetic acid (2,4-D) herbicides are associated with canine malignant lymphoma.

OVERALL PANEL FINDINGS

Although the study, by virtue of its title, suggests a relationship between exposure to 2,4-D and canine malignant lymphoma, this hypothesis was not strongly supported by any of the results presented. The increases in risk suggested by the odds ratios reported (e.g., OR=1.3) were small. Therefore, it is possible that a small bias or confounder could be responsible for the elevated odds ratio instead of a biological link to any of the potential exposures studied. Exposure quantification was very poor, and it is therefore difficult to discern what exposures were actually studied.

STUDY STRENGTHS

A relatively large sample size was used and the number of controls was about twice the number of cases, which allowed the authors to conduct analysis of many subgroups of dogs. Control dogs were selected from the same hospital as the case dogs, which is important in addressing the potential problem of selection bias. Two control pools were employed: one pool consisted of dogs diagnosed with tumors other than lymphoma, the other pool consisted of dogs that had died of other causes. This design should address the potential for biased recall among the owners of the case dogs. The control dogs were matched with case dogs by location, age and year of treatment. This matching should control confounding by these variables.

Although the response rate was relatively low (about 45%) by mail, 70% of those non-responders were interviewed, which is considered a good response rate for a study of this type. Combining the methods, the total response rate was about 83%. In addition, the questionnaire did not draw the attention of the owners to the a priori hypothesis that 2,4-D exposure predisposed dogs to canine malignant lymphoma. This approach should address the potential for recall and interview bias.

Continued on Page 2

In Memorium

We regret to inform you that Dr. Wendell R. Mullison, whom many of you knew as the voice of the 2,4-D hotline, died suddenly April 30 at the age of 78. Wendell was involved in some of the early research work and formulation advances for the herbicide 2,4-D. Having devoted more than 40 years of his life to the safe use of agricultural chemicals, Wendell was a persistent voice of reason and kindly practical experience in an age where many had lost touch with the realities of the green world. New arrangements will be made for staffing the hotline. But Wendell's voice, which has now been stilled, is going to be greatly missed.

Correction

In a previous issue of 2,4-Dispatch, we stated that the 1989 symposium convened by the Harvard School of Public Health had considered data from a subsequently published Saskatchewan farmworker study by Dr. Donald T. Wigel, et. al., in reaching conclusions about the weight of the evidence on 2,4-D and cancer. That statement was incorrect in that Dr. Wigel's research was not considered by the panel. Our apologies for the error.

Executive Summary

Continued from Page 1

STUDY WEAKNESSES

Biases

The study was poorly designed to investigate the hypotheses that 2,4-D causes cancer in dogs. Two sets of controls were combined in the final analysis but analyses specific to each control group were not presented to address the issue of potential recall bias. The authors should have analyzed the control groups separately and, only if the risks were comparable, should they have combined the two control groups.

Although the use of a hospital-based case-control design is generally considered to be less rigorous than a population-based design because of the greater opportunity for selection bias, the authors did not present what proportion of local dogs were seen at the three hospitals to identify possible differences between the groups. It is also likely that some of the dogs diagnosed with fatal canine malignant lymphoma would be euthanized by the local veterinarian rather than be taken to a hospital for treatment, thus, raising questions about the representativeness of the case series as well as the generalizability of the findings of the study.

There was substantial non-response to the mailed questionnaire. Forty-five percent of the subjects had to be phoned in order to obtain information and it is not clear whether these two groups were independently tested to assess potential biases and determine internal consistency for the study.

Misclassification and Confounding

In this type of study, it is desirable to quantify exposure both objectively and accurately. The questionnaire, however, is very non-specific and broad with regard to use of pesticides, and a list of names of home-garden products was not supplied. The design of several questions restricted responses in such a manner that it is not clear whether 2,4-D was used alone or in combination with other herbicides. Thus, the exposure quantification data were of no value and the combination of the two groups (commercial and homeowner) may not have been scientifically valid as there was no evidence that these groups were exposed to the same chemicals. A market survey of home-garden herbicide use in the U.S.A.[2] has shown that of those products containing 2,4-D only 15% contained 2,4-D alone. The remaining 85% contained other herbicides such as dicamba and MCPA in addition to 2,4-D. It is thus very likely that a high percentage of the dogs in the exposed groups were exposed to herbicides other than 2,4-D further complicating any link between 2,4-D and their cancer.

Data from the Hayes *et al.* study suggest that 33% of owners reported using 2,4-D only, which is more than twice the percentage reported in the U.S. market survey. This raises questions about the reliability (or possible misclassification) of the responses to the questionnaire.

Also supporting the possibility of misclassification is the reported response that some of the case owners applied the herbicide three and more times per year. Given the geographical locations of this study, it is not recommended and very unusual that 2,4-D would be used more than two times per year. The significant trend test for number of applications per year is driven by a significant number of dog owners who reported using 2,4-D four or more times per year. Since it would be surprising that even a small percentage of dog owners used 2,4-D four times per year, this raises serious questions about the reliability of the questionnaire with respect to quantifying this variable, as well as the reliability of the trend test.

The questionnaire is also inadequate with respect to gathering information about the potential confounder of viral causes of lymphoma. Therefore, the potential impact of viruses could not be tested for, or controlled.

Study Results

In addition to the poor designs of the study and the questionnaire, the results did not support the authors' hypothesis. The only statistically significant observation of a relationship between canine malignant lymphoma and lawn chemicals was observed when the data from three exposure groups and the two control groups were combined. When each of these sub-groups was analyzed separately, no statistical significance was observed.

The authors claim to have tested a number of associations in their study, listing some 35 factors in the tables and text. It is to be expected that one or more of these tests will show statistical significance purely on the basis of chance, particularly when the OR is small (e.g., OR=1.3). One would expect an OR of 2 or greater if a strong relationship existed.

Although the authors claim that a statistically significant trend was observed for the number of owner applications per year, this is not a meaningful dose-response as the "0" application or unexposed group should not be included in the trend test. With this point excluded, the trend is not significant. In addition, there was no statistically significant trend observed for number of commercial applications of lawn chemicals per year, which is not in concordance with the authors' claim of a statistically significant trend for owner applications.

Finally, other studies on humans[3] and animals[4,5,6,7] exposed to 2,4-D do not support the findings of this study.

CONCLUSION

As a result of limitations in the design of the study, it may be concluded that it did not show an association between dog owner's use of 2,4-D and canine lymphoma.

REVIEW PANEL

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[1] Hayes HM, Tarone RE, Cantor KP, Jessen CR, McCurnin DM, Richardson RC. Case-control study of canine malignant lymphoma: positive association with dog owner's use of 2,4-dichlorophenoxyacetic acid herbicides. J Natl Cancer Inst 1991; 83:1226-1231.

[2] Page D. Personal communication. Dow, 1991.

[3] Harris SA, Solomon KR, Bowhey C, Stephenson GR. Human exposure to 2,4-D following controlled activities on recently sprayed turf. J Environ Health Sci 1992; B27:9-22.

[4] Arnold EK, Beasley VR, Parker AJ, Zachary JF, Lovell R, Sawchuck S, Richardson B, Butcher M. The toxicological evaluation of the dimethylamine salt of 2,4-dichlorophenoxyacetic acid (2,4-D) in the dog. Report of the College of Veterinary Medicine, University of Illinois, Urbana, IL. May 1987.

[5] Arnold EK, Lovell RA, Beasley VR, Parker AJ, Stedelin JR. 2,4-D toxicosis III: An attempt to produce 2,4-D toxicosis in dogs on treated grass plots. Vet Hum Toxicol 1991; 33:457-461.

[6] Hansen WH, Quaife ML, Haberman RT. Chronic toxicity of 2,4-dichlorophenoxyacetic acid in rats and dogs. Toxicol Appl Pharmacol 1971; 20:122-129.

[7] Hazelton Laboratories. Combined toxicity and oncogenicity study in rats, 2,4-dichlorophenoxyacetic acid. Final report. Volume 1. Hazelton Laboratories America, Inc., Vienna, VA. May 29, 1986. Project No. 2184-103.

2,4-Dispatch and *2,4-Dispatch/Flash* are news and information bulletins about 2,4-D and phenoxy herbicides published by the Industry Task Force on 2,4-D Research Data. Issues will be published on a periodic basis as news and information becomes available. Feel free to share this information with others who want or need to know the facts about this beneficial agricultural tool.

J. ENVIRON. SCI. HEALTH, B27(1), 9-22 (1992)

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HUMAN EXPOSURE TO 2,4-D FOLLOWING CONTROLLED ACTIVITIES ON RECENTLY SPRAYED TURF

KEYWORDS: pesticide, herbicide, 2,4-D, exposure, human, bystander, public, turf, grass.

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ABSTRACT

Total body dose of 2,4-D was determined in 10 volunteers following exposure to sprayed turf 1 hour following application and in 10 volunteers exposed 24 hours following application. Each group of 10 volunteers was divided in half and five wore long pants, a short-sleeved shirt, socks and closed footwear. The other five wore shorts and a short-sleeved shirt and were barefoot. All volunteers were exposed to a 2 by 15 m area of turf for 1 hour during which they alternated between walking and sitting or lying on the turf surface for intervals of 5 minutes. Dislodgeable residues of 2,4-D taken during the exposure sessions showed a rapid decline from 1 hour following application (8%) to 24 hours following application (1%). No detectable residues were found in 4-day urine

samples supplied by volunteers except for 3 people who were barefoot and wearing shorts and contacted the turf 1 hour following 2,4-D application. The highest dose was measured in a volunteer who removed his shirt for 30 minutes of the exposure session (426 μg). Exposure levels of the other two volunteers who wore the prescribed clothing were lower (153 and 103 μg). No detectable residues were found in urine samples supplied by volunteers exposed to sprayed turf 24 hours following application. These results indicate that at the doses measured, exposure to sprayed turf should present little risk in humans. However, people can reduce exposure to non-detectable levels by remaining off treated turf for a period of 24 hours or until after rainfall or irrigation so that dislodgeable residues and therefore potential exposure are essentially zero.

INTRODUCTION

Public concern regarding the use of pesticides on residential and publicly accessible areas has prompted the Ontario Provincial Government to require posting of all professional pesticide applications. These regulations, which exclude the homeowner applicator, require the posting of signs which bear the message "KEEP OFF". These signs must be posted at the application site for a period of up to 24 hours before and 48 hours after the pesticide application.

The general public may be exposed to turf pesticides by dislodging them from treated plant surfaces. Recent studies (Thompson *et al.*, 1984) have shown that a maximum of 6% of the originally applied amount of 2,4-D can be dislodged from the turf immediately after spraying. When the application is

2,4-D at the application site; and to determine appropriate re-entry periods for the general public following application of pesticides to private and public areas.

MATERIALS AND METHODS

The re-entry periods tested in this study were 1 hour and 24 hours following 2,4-D application. The same area of turf was used for both exposure periods which were conducted 1 month apart under similar weather conditions. No rainfall occurred on either exposure day.

Volunteers

Volunteers were chosen from faculty, staff and students at the University of Guelph. Ten volunteers, consisting of two females, aged 22 and 25, and eight males ranging in age from 22 to 55 participated in the exposure session 1 hour following the pesticide application, and 24 hours following pesticide application, ten volunteers consisting of two females, aged 25 and 31, and eight males aged 22 to 61 took part in the study. Prior to both studies, the volunteers were split into two groups Five of the participants wore long pants, a t-shirt, socks and closed footwear. The other five wore shorts and a t-shirt and were barefoot. All volunteers were supplied with written information outlining the possible risks they would be taking to participate in the study. It was estimated that no higher than 1 mg total dose would be possible. The protocol was appraised and approved by the University of Guelph Ethical Review Board and Consent forms were signed before the initiation of the study.

Application

The area of turf used was mowed three days in advance of each study to

level out the grass surface. Ten areas of 2 m by 15 m were marked out side by side with a bright yellow rope pegged into the ground. Five areas of 1 m by 1 m were marked out for the dislodgeability portion of the study. A professional lawn care company representative of the industry in Ontario was asked to apply the pesticide on both dates. A mixture of 2,4-D amine/mecoprop/dicamba (190:100:18 g/L) was used at a rate of 1.0 kg a.e.(acid equivalent)/ha. Theoretically, 3.3 g of 2,4-D a.e. were present in each 2 by 15 m plot and 0.11 g a.e. in each 1 m by 1 m plot. The plots were sprayed cross wise so that any overlap in the spray pattern would be identical in each plot.

Exposure

The volunteers arrived at the spray site between the period of 12:00 and 12:15 p.m. and were randomly assigned to plots. At 12:30 (1 hour and 24 hours after the completion of the spray application) they were asked to step into their plots and begin the 60 minute exposure session. The volunteers were instructed to walk on the turf for a period of 5 minutes and then sit or lie on the area for 5 minutes and to continue in this fashion for 50 more minutes. Each person was asked to cover the largest area possible in the plot while walking and to expose the greatest area of their body while lying or sitting on the plot. Volunteers sat on six different areas of the plot to facilitate maximum exposure. One volunteer in the 1-hour exposure session removed his shirt during the last 30 minutes of the study. The whole exposure period was videotaped. Following the 60 minute exposure, the participants were allowed to wash their hands and were served a picnic lunch on an adjacent unsprayed area of turf.

Dislodgeable residues of 2,4-D

During the 1 hour exposure period, dislodgeable residues were determined by vigorous wiping of five, 1 m^2 plots as described by Thompson *et al.*, 1984. A pair of running shoes was covered with disposable polyethylene plastic bags and a double layer of cheesecloth, tied above the ankle. The cheesecloth was moistened with distilled water and the sampling was performed by scuffing backwards and forwards across the grass in a 1 m^2 area for 1 minute while wearing the covered shoes. The cheesecloth was removed from the shoes, and the excess unexposed material was cut away. The cheesecloth sample was immediately immersed in acetone and transported to the laboratory for extraction.

Biological monitoring

To check for previous exposure to 2,4-D, a morning urine sample was obtained from the volunteer on the day of exposure and was stored in a refrigerator in 500 mL NALGENE bottles until it was picked at noon hour. Sub-samples of approximately 100 mL were taken from the morning pre-exposure samples supplied and were spiked with 22 μg 2,4-D acid dissolved in methanol to serve as field recovery checks. Spikes were stored in 125 mL or 500 mL NALGENE bottles and were returned to the volunteers following the 1 hour exposure session. Volunteers were instructed to store the spiked samples with their day 1 samples either in the refrigerator or soft sided cooler bags with frozen ice packs.

Immediately following application, the volunteers were instructed to collect all urine for a consecutive 4 day period. A minimum of 4 clearly labelled

2 L NALGENE bottles were supplied to each volunteer, one or more for each day.

Upon arrival in the labbratory, the volumes of all samples (pre-exposure, spike, day 1, 2, 3 and 4) were measured and 1 ml sub-samples were taken from day 1, 2, 3 and 4 samples and analyzed for urinary creatinine. Urinary creatinine is a waste product of creatine which is necessary for muscle metabolism, and it is formed by an irreversible reaction at a fairly constant rate. It is commonly used as an index of the completeness of 24-hour urine collections (Murphy and Henry, 1979).

Sample Analysis

Laboratory procedures used to analyze air and urine samples were similar to those described by Libich *et al.* (1984) and Frank *et al.* (1985). Dislodgeable residues of 2,4-D were analyzed as described by Thompson *et al.* (1984).

RESULTS AND DISCUSSION

Dislodgeable residues of 2,4-D

Dislodgeable residues of 2,4-D determined 1 hour and 24 hours following application (Table I) were similar to those found by Thompson *et al.*,(1984) who found that less than 6% could be dislodged immediately after spraying at a rate of 2.24 kg a.e./ha and 4.5% when sprayed at a rate of 1.0 kg a.e./ha. Although residues determined in this study were slightly higher, they showed a similar rapid decrease over time. Higher dislodgeable residues may have been due to spraying techniques used, weather conditions and the composition of the turf

surface. It should also be noted that a professional applicator applied the pesticides and the researchers had no control over the rate. This may have resulted in higher than recommended rates applied to the plots. Results of these dislodgeablility studies cannot be directly statistically compared because experiments were conducted 1 month apart. These results do however, allow for a comparative estimation of human exposure based on amount of dislodgeable residues at the time of exposure.

Similar comparisons have been attempted by other researchers. Zweig *et al.* (1985) determined the relationship between dermal pesticide exposure by fruit harvesters and dislodgeable foliar residues of captan, vinclozolin, carbaryl, and methiocarb. A positive correlation between these two parameters was found and log-log regression analyses were essentially linear between dislodgeable foliar residues and dermal dose rates. The authors proposed that a rough first approximation of dermal exposure rate for fruit harvesters based on dislodgeable foliar residues (DFR) can be calculated using the following expression:

$$\text{Dermal Exposure Rate (mg/hr)} \approx 5 \times 10^3 \times \text{DFR}$$

This transformation suggests a method for obtaining exposure rates of fruit harvesters in order to obtain safe re-entry periods without involvement of human subjects. However, this equation does not account for variation in percutaneous penetration of different pesticides and does not allow for the calculation of total dose, which is more relevant to human health risk assessment.

A herbicide which may be highly dislodgeable from leaf or plant surfaces (which indicates high dermal exposure rates) may be poorly absorbed through

Table I
Dislodgeable Residues of 2,4-D Applied to Turfgrass 1 Hour and 24 Hours Post Application.

	Dislodgeable Residue - 1 Hour		Dislodgeable Residue - 24 Hours	
Plot	mg/m^2	% of Applied	mg/m^2	% of Applied
1	10.030	9.118	1.166	1.060
2	10.952	9.956	1.161	1.055
3	8.200	7.455	1.024	0.9309
4	4.904	4.458	1.080	0.9818
5	8.144	7.085	1.156	1.051
$\bar{X} \pm SE$	8.45 ± 0.927	7.61 ± 0.949	8.12 ± 0.028	1.02 ± 0.026
Control	ND[1]	NA[2]	ND	NA

1 Non-detectable < 5 μg/L
2 Not applicable

human skin thus reducing potential exposure. Studies conducted by Feldmann and Maibach (1974) indicate that, of 12 pesticides tested, carbaryl was almost completely absorbed (73.9%) following topical administration to the ventral forearm, and diquat showed only slight penetration. All other compounds tested ranged between 5 and 20% absorption. These absorption factors will dramatically affect total dose absorbed in humans and must be considered when establishing re-entry periods.

Human Exposure

Total dose of 2,4-D found in 96 hour urine samples supplied by volunteers is presented in Tables II and III. Creatinine values were calculated in mmoles from daily volume measurements for four 24 hour periods for each volunteer and

Table II
Total Dose of 2,4-D Found in Urine Samples Supplied by Volunteers Exposed to Turf 1 Hour Following a 2,4-D Application.

Vol.#	Weight (kg)	Creatinine mmole/day	Spiked Recovery	Baseline Exposure	Total µg 2,4-D	2,4-D µg/kg
1 shorts	100.0	19.86	76.01	ND[1]	153.06	1.53
2 shorts	95.5	19.87	84.36	ND	ND	0.00
3 shorts	63.6	11.37	89.48	ND	ND	0.00
4 shorts	45.5	7.12	113.4	ND	103.06	2.27
5 shorts	79.5	18.00	97.54	ND	426.44	5.36
6 pants	77.3	14.84	97.92	ND	ND	0.00
7 pants	68.2	9.83	81.82	ND	ND	0.00
8 pants	72.7	12.29	99.90	ND	ND	0.00
9 pants	65.9	14.67	76.29	6.58	**	**
10 pants	79.5	15.20	lost	ND	ND	0.00

1 Non-detectable < 5 µg/L; **removed from study due to positive baseline exposure

a mean of the 4 days is reported. All creatinine values were above or fell within the normal range for adult females (5.0 - 16.0 mmole/24 hours) and for adult males (7.0 - 18.0 mmole/24 hours), and showed little variation on a daily basis, indicating complete sample collection.

The highest exposure encountered in a volunteer (#5, shorts) occurred 1 hour following application and was found in a volunteer who removed his shirt for 30 minutes of the exposure period. The extra area of skin exposed to the turf surface during the exposure session may account for the increase in total dose calculated. Exposure of Volunteer #5 was at least two times higher than other

Table III
Total Dose of 2,4-D Found in Urine Samples Supplied by Volunteers Exposed to Turf 24 Hours Following a 2,4-D Application.

Vol.#	Weight (kg)	Creatinine mmole/day	Spiked Recovery	Baseline Exposure	Total µg 2,4-D	2,4-D µg/kg
1 shorts	100.0	18.83	81.79	ND[1]	ND	0.00
2 shorts	77.3	13.5	103.51	ND	ND	0.00
3 shorts	63.6	10.66	79.41	ND	ND	0.00
4 shorts	79.5	11.86	95.02	ND	ND	0.00
5 shorts	72.7	11.78	84.43	ND	ND	0.00
6 pants	75.0	13.94	121.40	ND	ND	0.00
7 pants	63.6	8.42	88.26	22.82	**	**
8 pants	67.3	11.20	84.49	ND	ND	0.00
9 pants	65.9	14.04	73.5	ND	ND	0.00
10 pants	100.0	15.03	113.89	ND	ND	0.00

1 Non-detectable < 5 µg/L
** removed from study because of positive baseline.

due to positive baseline exposures. These results indicate that the area of skin exposed to treated surfaces can affect total dose absorbed. This broad statement does not account for variations seen within the 1 hour exposure group wearing shorts. As with all human experiments, the individual variation between subjects is the most difficult to control. The absorption of pesticides through human skin occurs at different rates and personal habits (i.e. how people sit or lie) may affect either area of contact with the treated surface or the anatomic site of the body exposed. The time before bathing or showering will affect the absorption of the volunteers wearing shorts when considering both total dose and dose on a mg/kg

body weight basis. No 2,4-D was detected in urine samples of volunteers wearing long pants and closed footwear (Table II) or in either group 24 hours following application (Table III). Two volunteers were removed from the study pesticide and various other factors such as amount of exercise and sweating, and the wearing of contaminated clothing, may affect absorption.

The relationship between total dose and dislodgeable residues of 2,4-D is shown in Table IV. Average total dose for the 1 hour re-entry period was calculated from volunteer #'s 1 and 4 total dose measurements assuming a worst case scenario but, for sake of comparison with the 24 hour re-entry period, volunteer # 5 was not included. An absorption factor was calculated by dividing the amount of 2,4-D (mg) available for human contact by the average of the two exposures. This factor was used to estimate the theoretical total dose of 2,4-D which could be found in urine samples of volunteers in the 24 hour re-entry exposure session. This dose was calculated at 16.8 μg. This is the theoretical amount of 2,4-D that would be recovered in a volunteer who wore shorts and showed no variation with the two volunteers in the 1 hour exposure session. All five volunteers had urine volumes of at least 4 litres, over the 4 day period, which would reduce exposure to non-detectable levels (5 ppb). It is thus possible that these people were in fact exposed, but below the limit of detection.

In summary, it appears that type of clothing worn during exposure to sprayed turf will affect the total dose absorbed in a human. In addition, as dislodgeable residues decline, human exposure to 2,4-D will decrease. The highest total dose calculated in any volunteer was less than 0.5 mg. This is much

Table IV
The Relationship Between Dislodgeable Residues and Total Dose of 2,4-D Calculated in 2 Volunteers.

	1 Hour	24 Hours
Amount of 2,4-D applied in each plot (g):	3.3	3.3
Percent dislodgeable:	7.6	1.0
Amount of 2,4-D available for human contact (mg):	251	33.0
Average total dose (μg):	128[1]	16.8[2]
Absorption factor:	1961	1961

1 Average of volunteer #'s 1 and 4.
2 Theoretical dose estimated by dividing amount available for human contact with absorption factor.

lower than the acceptable daily intake of 23.9 mg (0.3 mg/kg/day) suggested by the World Health Organization (WHO, 1984). However, people who wish to reduce exposure to non-detectable levels, can remain off treated turf for a period of 24 hours or until after rainfall or irrigation so that dislodgeable residues and therefore potential exposure are essentially zero.

It must also be considered that children may be exposed to sprayed turf by routes uncommon to adults. Adult exposure is mainly dermal, while oral and inhalation exposure are minimal for 2,4-D. Children may eat grass or dirt and ingest the pesticide. This should be taken into consideration when advising the public on exposure reduction practices.

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REFERENCES

Feldmann, R.J., and Maibach, H.I. Toxicol. Appl. Pharm., 28, 126-132 (1974).

Frank, R., Campbell, R.A., and Sirons, G.J. Arch. Environ. Contam. Toxicol. 14, 427-435 (1985).

Libich, S., To, J.C., Frank, R. and Sirons, G.J. Am. Ind. Hyg. J., 45, 56-62 (1984).

Maibach, H.I., Feldman, R.J., Milby, T.H., and Serat, W.F. Arch. Environ. Health, 23:208-211 (1971).

Murphy, J.E. and Henry, J.B. Clinical Diagnosis and Management by Laboratory Methods. W.B. Saunders Company, Philadelphia (1979), pp. 262-264.

Thompson, D.G., Stephenson, G.R. and Sears, M.K. Pestic. Sci. 15, 353-360 (1982).

WHO. 2,4-Dichlorophenoxyacetic acid. World Health Organization, Environmental Health Criteria 29. Geneva, (1984).

Zweig, G., Leffingwell, J.T., and Popendorf, W. J. Environ. Sci. Health, 20:27-59 (1985).

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VEGETATION MANAGEMENT STEERING COMMITTEE
COMMITTEE REPORT
REGION 4

by Garth Baxter Regional Pesticide Specialist

OVERVIEW OF REGIONAL PROGRAMS

PESTICIDE TECHNOLOGY DEVELOPMENT

NAPIAP

A two year study was completed, with Utah State University, on "Tall Larkspur Control on High Elevation Rangelands: Assessment of Herbicide Application Techniques and Environmental Impacts". It compared the effectiveness of glyphosate, metsulfuron, and picloram on the control of this important poisonous plant on rangeland. It also compared the herbicide residues of the three products in runoff water and soil depths. A summary of the report is enclosed.

We have just started a two year study with Utah State Water Resources Laboratory on "Influences of Soil Organic Matter Type and Quantity on the Sorption Behavior of Selected Pesticides in Forest and Rangeland Soils". The products being tested include sulfometuron methyl, trichlopyr, and hexazinone.

VEGETATION MANAGEMENT.

The past two years a number of demonstration plots have been put in throughout the Region for the use of herbicides in controlling undesirable vegetation in timber site preparation and release. These studies have been expanded to include the control of brush on ski areas and for right-of-way maintenance. There is a considerable amount of competing and unwanted vegetation in the Region in timber sale areas. The herbicide tool has not been used in managing this problem. Low impact methods of vegetation management were employed in the demonstrations. The studies are now complete and the results will be prepared this winter. This work was done in conjunction with Max Williamson, Vegetation Management Specialist. Max will be making a presentation at this meeting explaining these methods.

Demonstration plots have also been put in the past two years on especially problemsome noxious weeds and range weeds which we have only been marginally successful in controling. Most of these studies involve the sulfonyl urea herbicides of chlosulfuron, sulfometuron, and metsulfuron. These studies are complete and are now in the process of being analyzed.

RISK ASSESSMENT.

The Region coordinated the preparation of the "Risk Assessment for Herbicides Used in Forest Service Regions 1, 2, 3, 4, 10 and Bonneville Power Administration Sites". This has been a major effort the past two years. This document is now complete. Training is now underway for Forest and District Pesticide Coordinators and other resource people who will be incorporating this in their site specific vegetation management projects. This Training is being provided in Region 4 and to some of the other Regions.

CONTROL PROJECTS

NATIONAL FOREST PROJECTS WITHIN THE REGION
Enclosed is sheet showing the summary of pesticide projects within the Region for 1991. The 1992 reports are not in at this date but the program is similar to 1991. You will note that the Region pesticide program is not especially large but it is quite diverse.

Enclosed also is a sheet indicating the historic and projected vegetation management programs with herbicides in Region 4. This information is compiled from material supplied by the Forests. The huge increases projected for the future program reflects the amount the Forests estimated they would do after the Risk Assessment is completed. These acres appear very ambitious and are probably not realistic to achieve but they do indicate a strong need and desire on the part of our field people to use herbicides in vegetation management. It is interesting to note that in the past 5 years, 96% of the herbicide vegetation management program in R-4 has been in range or noxious weed control. The future projection, after the Risk Assessment is now completed, is for 98% of the herbicide use to be in the range or noxious weed program in the Region. Noxious weeds are normally found on range land and are administered through the range program. I suspect that Regions 1, 2, and 3 might show a similar interest. This all points the need to have experts in the range resource as well as forestry represented on the Vegetation Management Steering Committee. This is not the current case.

Tall Larkspur Control on High Elevation Rangelands:
Assessment of Herbicide Application Techniques
and Environmental Impacts

Larkspur control summary

Glyphosate was most effective on both species of larkspur at both locations. The spray application of glyphosate was more effective than the roller. But glyphosate, being nonselective, killed most of the desirable perennial species. Weedy annual forbs and rhizomatous forbs increased following spray application, at Oakley. The roller applicator was not as detrimental to cover and production of perennial forbs and grasses as the spray. However, the other selective herbicides allowed grass production to increase more than did glyphosate.

Metsulfuron was more effective on duncecap larkspur at Oakley than tall larkspur at Manti. It killed 70-81% of duncecap larkspur with the spray application at 1.1 and 2.2 kg/ha respectively. However, Ralphs et al. (1992) reported kill rates near 100% on the same site in previous years. Control of tall larkspur at Manti was very low. The cool weather and unfavorable growth conditions at the subalpine zone in the early growth stages may limit the usefulness of metsulfuron on these sites. There was no difference in application methods at Oakley, but the roller applicator gave a better kill of tall larkspur than the spray at Manti. Metsulfuron allowed grasses to increase more than the other herbicides.

Picloram was more effective on tall larkspur at Manti than on duncecap larkspur at Oakley. However, the 2.2 kg/ha spray rate killed greater than 85% of larkspur plants at both locations. There was no difference in application methods at Manti, but the roller was much less effective at Oakley. Picloram allowed grass cover and production to increase, but the higher rates limited the amount of increase in grass cover and production at Manti.

HISTORIC AND PROJECTED ANNUAL VEGETATION MANAGEMENT WITH HERBICIDES

Intermountain Region - Forest Service

	Past 5 Years Average	Future/Annual Projected
Site Prep and TSI	46	3,800
Range	730	14,754
Wildlife and Fish	71	675
Recreation	2	16
Special Uses	73	367
Corridors/Minerals	7	198
Roads/Facilities	286	405
SUB TOTAL	**1,215**	**20,215**
Noxious Weed	* 9,700	** 204,000
TOTAL	**10,915**	**224,215**

References: Responses to 2100/1950 letter to R-4 Forest Supervisors (11/29/88) requesting historic and projected data for Vegetation Management EIS.

* Acres treated in 1991.
** [redacted] Acres based on projections estimated in the 1986 Intermountain Region Noxious Weed EIS.

1991 PESTICIDE USE
Intermountain Region

INSECTICIDE AND PHEROMONES

Western Pine Beetle	1,150	Trees	Pheromones
Gypsy Moth	30,000	Acres	Bt
Tussock Moth	600	Acres	Pheromones
D.F.Beetle	500	Trees	Pheromones
Mormon Cricket	3,548	Acres	Carbaryl
Grasshoppers	--------		--------
Mosquito Control	18	Acres	Bt

FUNGICIDES

Nursery Root Rot	23	Acres	Fungicide

HERBICIDES

Noxious Weed Control	9,674	Acres	Herbicides
Range Management	874	Acres	Herbicides
R-O-W	60	Acres	Herbicides
Poisonous Plants	98	Acres	Herbicides
Nursery Weeds	33	Acres	Herbicides
General Weed Control	150	Acres	Herbicides

MISCELLANEOUS

Undesirable Fish Control	15,600	A/F	Rotenone
Pocket Gophers	7,582	Acres	Strychnine
Predators	--------		Sodium Cyanide

HISTORIC AND PROJECTED ANNUAL VEGETATION MANAGEMENT WITH HERBICIDES

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* Acres treated in 1991.
** Total 1991 acres based on projections estimated in the 1986 Intermountain Region Noxious Weed EIS.

Smith

EXECUTIVE SUMMARY

The U.S. Department of Agriculture (USDA) Forest Service (FS) Regions 1, 2, 3, 4, and 10 and the Bonneville Power Administration (BPA) have proposed to use various herbicides, carriers, and additives in programs to control unwanted vegetation. The programs are proposed to be carried out on rangeland, forestland, facilities, rights-of-way, recreation (administration), and riparian sites. A risk assessment was conducted to determine what human health risks and what risks of effects to nontarget species are posed by potential exposures to 21 herbicides and 4 carriers (or additives) as listed below:

- *Herbicides:*

  Amitrole
  Atrazine
  Bromacil
  Chlorsulfuron
  Clopyralid
  2,4-D
  Dicamba
  Dichlobenil
  Diuron
  Glyphosate
  Hexazinone
  Imazapyr
  Mefluidide
  Metsulfuron methyl
  Picloram
  Prometon
  Simazine
  Sulfometuron methyl
  Tebuthiuron
  Triclopyr
  Trifluralin

- *Carriers (or additives):*

  Diesel oil
  Limonene
  Kerosene
  Mineral oil

Nonchemical methods including manual, mechanical, biological, and prescribed burning techniques are also proposed to control unwanted vegetation. A description of the manual, mechanical, and biological methods and an evaluation of the risks of prescribed burning are presented in this document in addition to the chemical risk assessment.

Chapter I introduces the risk assessment document. Chapter II examines the nonchemical control methods used to control unwanted vegetation and provides a human health risk assessment for exposure of members of the public and workers to fire, smoke, and volatilized herbicides from prescribed burning operations.

Chapter III, consisting of eight sections that comprise the bulk of the document, examines the health risks to humans and the risks to nontarget species from the use of chemical control methods to manage unwanted vegetation. Sections III-A and III-B describe the risk assessment methods and the vegetation management programs evaluated for risk. Sections III-C, III-D, and III-E present the human health hazard analysis, exposure analysis, and risk

analysis, respectively. Sections III-F, III-G, and III-H present the nontarget species hazard, exposure, and risk analyses.

HUMAN HEALTH RISK ASSESSMENT METHODOLOGY

The methodology for this risk assessment employed three principal analytical elements–hazard analysis, exposure analysis, and risk analysis–to characterize the potential adverse health effects of human exposures to the herbicides and carriers.

Human Health Hazard Analysis

The human health hazards associated with using each herbicide or carrier were determined from extensive literature searches and relevant data submitted to the Environmental Protection Agency (EPA) in support of each of the pesticide's registration. This information was reviewed in particular to identify toxicity reference levels determined in laboratory animal studies for comparison with estimated program doses. The reference levels used in the risk assessment included systemic effect no-observed-effects levels (NOELs), reproductive/developmental NOELs, threshold limit values (TLVs), and cancer potencies (cancer slope factors). The neurotoxicity, immunotoxicity, genotoxicity, carcinogenicity, and synergistic effects of each herbicide and carrier were reviewed to develop the weight-of-evidence discussions for those endpoints.

Where data were lacking or scientific uncertainty existed for a particular pesticide about a specific toxic effect—for example, genotoxicity—the basis for the uncertainty was identified. Where possible, for the purposes of the risk assessment, a conclusion was drawn about whether the chemical might cause the effect in question based on the weight-of-evidence of all pertinent available data. Where sufficient ancillary data did not exist, no conclusion was drawn about whether the chemical might cause the effect in question.

Human Health Exposure Analysis

Herbicides used in the programs are proposed to be applied by four methods –aerial application, backpack, ground mechanical, and hand application.

For each application method, two human populations were evaluated in terms of their potential to be exposed to the herbicides and carriers. The first population at risk consisted of members of the public who live or work nearby, or who visit an area where the herbicides are being applied. These individuals may come into contact with the herbicide during application via spray drift or after application by touching contaminated surfaces or consuming contaminated water or food items. The second group at risk were the workers participating in the application operations. Workers included fuel truck drivers, pilots, mixers, loaders, applicators, and individuals who may perform more than one of these functions.

Exposure scenarios were developed for each application type to estimate doses to the public and to workers of each pesticide used in that application type. The scenarios took into

account the potential route of exposure, the relevant characteristics of the individual exposed, the time of inception and the duration of the exposure, the distance from the treated area, and the level of protection against receiving a dose from such an exposure that the person might possess.

In most cases, three levels of exposure were analyzed for both members of the public and workers: routine-typical, routine-extreme, and accidental. In addition, on facilities and riparian sites, backpack application may be used to apply herbicides up to the water's edge. In these cases, an additional level of exposure was included to account for this practice.

It is important to note here that the risk assessment does not quantify the probability or likelihood that any single member of the public will be exposed, but rather estimates public health risk assuming an individual is exposed under a given set of circumstances. In fact, the chances that any member of the public will actually be exposed in these operations are expected to be extremely low because of the remoteness of most application sites and because of the standard operating procedures the agencies employ to keep the public out of treated sites. Thus, the routine-typical public exposure scenarios were designed to estimate the most likely level of exposure that would occur assuming a person is exposed under the prescribed set of circumstances. The routine-extreme scenarios were designed to estimate what could be the highest exposure levels likely to occur, again assuming a person is exposed under the same set of circumstances. The accident exposures scenarios were designed to estimate the level of exposure that could occur to a member of the public only in the event of an emergency situation, such as a spill or aircraft jettison.

Exposures to members of the public were determined by evaluating the transport and fate of the pesticide in the environment and estimating the amount to which a person might be exposed by each potential exposure route. This methodology required knowledge of specific attributes of each pesticide used to determine its movement and fate in the environment after application and its persistence on different environmental surfaces and in various environmental media. Also important in this analysis were the distances between the edge of the treated area and the person themself or the items which the person might contact or ingest. These distances varied for each type of application–aerial, backpack, and ground-mechanical applications–and for the routine-typical, routine-extreme, and accident scenarios. Exposure to hand applications was not considered due to minimal drift.

Exposures to members of the public near the treatment area during or just after an application were evaluated for a variety of scenarios. These scenarios were chosen to represent the range of activities persons might be engaged in near these sites. Scenarios involving single routes of exposure included dermal exposure to offsite drift or vegetation or dietary exposure to water contaminated with offsite drift residues, contaminated fish, or berries. Scenarios involving multiple routes of exposure included both dermal and dietary exposures to hikers, berries pickers, anglers, or nearby residents. Assumptions of drift distances, offsite drift deposition, consumption amounts, and other parameters needed to calculate doses are provided in detail in this document. Inhalation exposure was not considered in the public exposure scenarios, due to the small contribution an inhalation dose would make to the total dose and the remote chance of inhalation occurring.

Exposures to workers were determined by extrapolating from doses found in field studies of similar types of pesticide applications. These studies most often based exposure estimates on an analysis of worker urine samples. Studies of this type were used where the work assignments were similar enough to the field study assignment to make the extrapolation appropriate. In estimating worker risk, information was used about the application equipment employed by each worker, the total amount of active ingredient applied on a daily basis, dermal penetration of each chemical, and the protective clothing worn during routine-typical and routine-extreme applications.

Scenarios developed for accidental exposures of both members of the public and workers included a direct spray of a person, direct spray of vegetation or water, immediate reentry into a treated area, and spills or jettisons of concentrated herbicides or mixtures.

Human Health Risk Analysis

Human health risks were evaluated in this risk assessment based on risk of systemic and reproductive/developmental health effects from chronic exposure, as well as the risk of cancer from repeated exposure to those substances considered possible carcinogens by EPA. In the prescribed burning risk assessment, risks were quantified for exposure to polynuclear aromatic hydrocarbons (PAHs) and volatilized herbicides in smoke from prescribed burning operations. Human health risks from PAHs contained in smoke from burning of woody vegetation were evaluated based on risk of cancer from repeated exposures. Human health risks from herbicides used in brown-and-burn operations were quantified for both chronic and cancer risks. In the pesticide risk assessment, human health risks were evaluated for exposures to the herbicides and carriers used in broadcast applications and in spot treatments. Human health risks from the herbicides and carriers were evaluated for both acute and chronic effects and for cancer risk.

Chronic health risks from the herbicides used in brown-and-burn operations were evaluated by comparing the estimated herbicide concentration in the air to the TLV. The TLV is an exposure limit established by the American Conference of Governmental Industrial Hygienists and represents the air concentration a person can be exposed to 8 hours a day, 40 hours a week, for a working lifetime, without suffering adverse health effects or significant discomfort. The TLVs are described in the hazard analysis; the airborne concentrations are estimated in the exposure analysis. The risks of adverse health effects were evaluated in terms of a margin-of-safety (MOS), which is the ratio of the air concentration estimated in the exposure analysis to the TLV. Risk increases as the estimated air concentration approaches the laboratory toxicity level—that is, as the MOS decreases.

Systemic health risks from the herbicides and carriers used in broadcast applications and spot applications were evaluated by comparing the estimated doses for each pesticide in each scenario to the laboratory-determined toxicity levels noted in the hazard analysis. The toxicity levels are described in the hazard analysis; the doses were calculated for each scenario in the exposure analysis. The risks of threshold effects were evaluated in terms of a margin-of-safety (MOS), which is the ratio of the dose estimated in the exposure analysis to the systemic or reproductive/developmental NOEL. Risk increases as the estimated dose approaches the laboratory toxicity level—that is, as the MOS decreases. In general, where the

MOS for a given estimated dose was calculated to be 100 or greater, the dose is described as posing a low risk of health effects. Where the MOS is calculated as less than 100 but greater than or equal to 10, the dose is said to pose a moderate risk of health effects. MOS's less than 10 pose a high risk of health effects. Where EPA has used an uncertainty factor other than 100 in determining their "safe" lifetime dose level (reference dose or RfD), this risk assessment uses the EPA uncertainty factor to set the appropriate MOS criteria to determine whether an estimated program dose presents a low, moderate, or high risk of human health effects.

The risk of a pesticide causing cancer was evaluated differently because it is assumed that a pesticide that may cause cancer has some chance of causing it at any dose level. In this analysis, cancer risks were calculated only for chemicals for which EPA has established a cancer potency value. These chemicals included the PAHs (benzo(a)pyrene, benzo(c)phenanthrene, benzofluoranthenes, perylene, and benzo(g,h,i)perylene), amitrole, atrazine, bromacil, picloram, simazine, trifluralin, kerosene, and diesel oil. Cancer risk was calculated for various categories of persons who may be exposed to the chemicals, based on a number of daily doses averaged over a 70-year lifetime.

HUMAN HEALTH RISK ANALYSIS RESULTS

Risks From Prescribed Burning

The prescribed burning risk assessment quantified risks from exposure to PAHs found in smoke from burning operations. The risk assessment also quantified exposure to volatilized fractions of the herbicides 2,4-D, glyphosate, hexazinone, picloram, and triclopyr in smoke, due to their application prior to the prescribed burning operation.

The public cancer risk analysis for PAHs indicated that, although the risk of cancer from exposure to any one of the chemicals analyzed was less than 1 in 1 million, 200 exposures to a combination of the five PAH compounds analyzed produced a cancer risk sightly higher than 1 in 1 million. Worker cancer risks were determined to be greater than 1 in 1 million after 30 exposures to a combination of the analyzed PAHs.

To evaluate the risk from inhalation of airborne concentrations of the herbicides which may be applied prior to prescribed burning, the estimated airborne concentrations were compared to the TLVs for each herbicide. In all cases, the ratio of the TLV to the estimated airborne concentration indicated negligible risk of health effects from inhalation of these volatilized fractions. A cancer risk analysis was also performed for inhalation of the herbicide picloram. This analysis indicated a cancer risk of less than 1 in 1 million.

Risks From Herbicides and Carriers

Quantitative Risk Results

Risks to members of the public were determined from exposures to herbicides and carriers applied by aerial, backpack, and ground mechanical applications methods. Hand applications were not analyzed because they were not expected to expose the public, due to negligible drift and the small size of the areas treated. In general, low risks to the public were estimated during routine-typical operations for most herbicides and carriers considered for use in the programs. Exceptions were in the cases of diuron and trifluralin use in some scenarios. In routine-extreme operations, amitrole, atrazine, dichlobenil, diuron, prometon, simazine, and trifluralin all posed a moderate risk to members of the public in some scenarios. Furthermore, high risks of health effects were indicated from trifluralin use, due to its high bioconcentration potential in fish, in the scenarios involving human consumption of fish.

Scenarios were also developed in which herbicides and carriers may be applied up to the water's edge on facilities and riparian sites, using backpack applications. In the case of backpack applications to the water's edge on facility sites, moderate risks of health effects were indicated for amitrole, dichlobenil, diuron, prometon, and simazine. In addition, high risks of health effects were indicated for trifluralin, due to its high bioconcentration potential in fish. In the case of backpack applications to the water's edge on riparian sites, moderate risks of health effects were indicated for amitrole, diuron, and simazine.

In all cases under the routine-typical and routine-extreme scenarios, the cancer risk to members of the public was less than 1 in 1 million for those herbicides and carriers considered possible carcinogens by EPA.

Workers were at a much greater risk than members of the public from herbicides and carriers used in the programs. Risks to workers were examined from all four types of applications—aerial, backpack, ground mechanical, and hand applications. Given similar conditions, lower risks were observed for workers operating aerial and ground mechanical equipment, even though the total amount of active ingredient applied in a single day was higher with these types of equipment. Risks from applying chemicals with backpack and hand application equipment were higher, primarily because the proximity of the worker to the nozzle or orifice through which the chemical is released and to the container in which the chemical is carried, increase the likelihood that the worker will contact with the chemical one or more times and that the chemical will remain on the worker's skin for some period of time.

Under the routine-typical scenarios for aerial and ground-mechanical applications, moderate or high risks of systemic or reproductive/developmental health effects were indicated for the following herbicides and carriers on at least one types of site: amitrole, atrazine, 2,4-D, dichlobenil, diuron, prometon, simazine, trifluralin, and diesel oil. Of all worker types analyzed for aerial and ground-mechanical applications, the mixer/loaders in both operations were at the highest risk.

The herbicides and carriers indicated above as posing moderate or high risks to aerial and ground-mechanical workers also posed moderate or high risks to backpack and hand applicators treating some of the site types. In addition, moderate or high risks were indicated for the following herbicides and carriers on at least one of the site types: bromacil, hexazinone, mefluidide, tebuthiuron, triclopyr, and kerosene.

Under routine-extreme scenarios, many of the herbicides and carriers in the analysis showed up as potentially posing moderate or high risk of health effects. Only those herbicides and carriers with the lowest toxicity may be used under routine-extreme conditions with low risk of adverse effects.

Cancer risks to workers during routine operations were based on the average number of days in a lifetime a worker would apply each chemical. Based on the assumptions used in this analysis, many workers had a greater than 1 in 1 million risk of developing cancer from the use of amitrole, atrazine, bromacil, simazine, and trifluralin. In some cases, the risk of developing cancer from the use of atrazine or simazine were greater than 1 in 10,000.

Determination of risks from accidental exposures to herbicides and carriers was also included in this document. Public accident scenarios in which drinking water (or fish living in this water) is contaminated by herbicides or carriers being directly sprayed on the surface or jettisoned or dumped into the water body posed the highest risks. In these scenarios, many of the herbicides and carriers pose moderate or high risk of adverse health effects. In some cases, cancer risks in these scenarios were greater than 1 in 1 million for amitrole, atrazine, simazine, and trifluralin.

In the worker accident scenarios, many of the herbicides and carriers pose moderate or high risk of adverse health effects. In some cases, cancer risks in these scenarios were greater than 1 in 1 million for amitrole, atrazine, bromacil, simazine, and trifluralin, and greater than 1 in 10,000 for atrazine and simazine.

Qualitative Risk Results

Some health effects cannot be evaluated quantitatively and are therefore reviewed qualitatively. The health endpoints that are reviewed qualitatively include mutagenicity, neurotoxicity, immunotoxicity, and synergism.

The weight of laboratory evidence from numerous *in vivo* and *in vitro* tests that a chemical is mutagenic or genotoxic is a principal consideration in the determination of whether the chemical poses a risk of causing heritable mutations in germs cells, leading to genetic defects or disease in offspring, or of causing mutations in somatic cells that may lead to cancer. The weight of evidence indicates that the following herbicides are not mutagens for the purpose of this risk assessment: amitrole, chlorsulfuron, clopyralid, dichlobenil, glyphosate, hexazinone, imazapyr, mefluidide, metsulfuron methyl, picloram, sulfometuron methyl, tebuthiuron, trifluralin, and triclopyr. Bromacil was considered to have a low potential for mutagenic responses. The weight of evidence indicates that atrazine, 2,4-D, diuron, and simazine, and the carrier diesel oil are mutagenic. The level of risk these latter chemicals represent in terms

of causing human mutations is uncertain. Not enough information was available to evaluate prometon or dicamba for mutagenicity.

Neurotoxicity assays address the question of whether a test chemical causes damage to the human nervous system. The hen delayed neurotoxicity assay is the most widely employed to test for nervous system damage. Neurotoxic effects were observed in five of the herbicides that were evaluated. Bromacil, 2,4-D, dicamba, dichlobenil, and trifluralin may potentially cause neurotoxic effects. The level of risk of causing human neurotoxic effects that these chemicals pose is unknown. The herbicides amitrole and glyphosate did not cause neurotoxic responses in test animals. No information was available on the possible neurotoxic effects of any of the remaining herbicides.

A number of laboratory assays have been recommended by scientists to evaluate the risk that a chemical might adversely effect the human immune system. Immunoassays include tests for immunosuppression, uncontrolled proliferation, alterations of defense mechanisms, and allergic responses. Most herbicides have been tested in a single system, the dermal sensitization assay in guinea pigs. Several studies indicated that the following chemicals were not dermal sensitizers: chlorsulfuron, dichlobenil, glyphosate, imazapyr, metsulfuron methyl, picloram, tebuthiuron, and triclopyr. Hexazinone and prometon tested negative for dermal sensitization but further review of these studies is required by EPA before a determination can be made. The herbicide 2,4-D was not a dermal sensitizer; however, it did cause enhanced lymphocyte proliferation, immunostimulatory effects, and immunoglobulin-mediated allergic hypersensitivity. Atrazine, dicamba, and trifluralin did cause dermal sensitization. No information was available on the possible immunologic effects of the remaining herbicides in the program.

Synergistic effects can be caused by exposure to two chemicals simultaneously or within a short period of time. These effects are not predictable and their combined effect may be greater or different than the effects of the chemicals when taken alone. Synergism testing is done to determine if a test chemical's toxicity is enhanced (potentiation), reduced (antagonism), or unaffected when the chemical is administered with a second chemical. The herbicides 2,4-D and picloram produce dermal irritation in test animals when administered together, but not when taken alone. The toxic effects of kerosene may be potentiated by antiemetics, epinephrine, or alcohol. No information was available on possible synergistic effects for any of the other program chemicals.

WORKER RISK MITIGATION

A discussion was provided in the document to address methods of reducing risks to workers involved in herbicide application programs. An effective risk mitigation technique is to limit the amount of herbicide a single worker handles on any given day such that his dose does not exceed the low risk level. Tables have been provided in the document that indicate the maximum total amount in pounds of active ingredient that a single worker may handle daily with low risk of systemic or reproductive health effects. In most instances, the application rate needed for a particular purpose cannot be adjusted or the efficacy of the treatment may

be sacrificed. However, by altering maximum treatment area as needed application rates are determined, risks of worker health effects can be kept low. These tables may be used as a tool to plan applications, by the selection of the herbicide used, and the adjustment of application rate, application acreage, application equipment used, and types of workers exposed, with the goal of protecting worker health.

Several suggestions are also made in the document on ways to reduce worker risk without changing application schedules and strategies. The mitigating measures include ways to reduce the potential for herbicide residues to reach the skin surface, reduce the amount of time residues remain on the skin surface, and reduce the chances of recontamination.

To reduce the potential for herbicides to reach the skin surface, protective clothing and equipment checks should be routinely employed. Because most exposure for pesticide workers is through the dermal route, not through inhalation or dietary exposure, the use of protective clothing can substantially reduce worker doses. Fabric finishes and the use of an undergarment layer, such as a tee-shirt, also decrease the chemical dose received. Faulty equipment is the most obvious contributor to increased doses in all of the worker studies evaluated. By employing routine equipment checks for leaks and malfunctions and by promptly setting faulty equipment aside for repairs, unnecessary herbicide exposures can be avoided.

Washing and showering can be effective in reducing the amount of time herbicide residues remain on the skin surface. While herbicides are not absorbed instantaneously through the skin, over time some portion of the herbicide remaining on the skin surface will be absorbed. Therefore, by minimizing the remaining available pesticide on the skin surface, the dose to that worker may be reduced. Showers provided at the Forest Service and BPA facilities would ensure that workers have the opportunity to shower prior to engaging in other activities.

Reducing the chance of recontamination is also an effective method of reducing risk. Laundering practices are important in minimizing herbicide exposure. The availability of laundering facilities at the Forest Service facilities would help to reduce risk; herbicide residues on clothing could be transferred to car upholstery or items in the home and recontaminate workers when they contact the items again. Trucks and other equipment used throughout the day can be a source of recontamination for some workers; door handles, steering wheels, gear shift knobs, and seat covers could all become contaminated during the day. Workers could avoid significant recontamination of their hands if they wore a minimum of at least one pair of cotton gloves whenever they were driving or traveling in such a vehicle. To avoid general recontamination, separate washable absorbent cotton seat covers could be employed in vehicles used in the application operations. To further limit transference of herbicides to workers, the vehicle in which they travel to and from the application sites should not be used for other travel.

NONTARGET SPECIES RISK ASSESSMENT METHODOLOGY

The methodology for the nontarget species portion of this risk assessment employed the same three principal analytical elements as the human health risk assessment–hazard analysis, exposure analysis, and risk analysis–to characterize the potential adverse effects on selected representative wildlife and aquatic species from exposures to the herbicides and carriers.

Nontarget Species Hazard Analysis

The nontarget species hazard analysis summarized laboratory and field study findings that evaluated the toxicity of the herbicides and carriers to wildlife and aquatic species. In many cases, toxicity studies with laboratory animals were used in this risk assessment because of the lack of specific wildlife studies. The results of laboratory animal studies are considered to be representative of the effects that would occur in similar species in the wild.

The hazard involved in using each herbicide or carrier was determined from extensive literature searches and relevant data submitted to EPA in support of the pesticide's registration. This information was reviewed to determine toxicity reference levels for comparison with estimated program doses. The reference levels included oral median lethal doses (LD_{50}s) and median lethal concentrations (LC_{50}s) to be used in the quantitative risk assessment.

Nontarget Species Exposure Analysis

Wildlife doses were calculated for a group of wildlife species representative of those typically found in areas supporting rangeland, forest land, or riparian vegetation in the Rocky Mountain regions. These species represent a range of phylogenetic classes, body sizes, and diets for which biological parameters are generally available. Typical and extreme acute dose estimates were determined for each representative species for each of the three major exposure routes–dermal, ingestion, and inhalation. Because the herbicides degrade relatively rapidly and sites are normally treated only once per year, no analysis of chronic wildlife dosing was performed. Because the herbicides show little tendency to bioaccumulate (although several tend to bioconcentrate in aquatic environments), long-term persistence in food chains and subsequent toxic effects were not considered a problem and were not examined in the risk assessment.

Aquatic species exposures were estimated for a group of representative aquatic species typically found in the Rocky Mountain regions. The analysis assumed that the aquatic organisms were exposed to herbicide residues by immersion in water bodies that had received varying levels of herbicide through drift or direct spraying. Two types of water bodies were employed in this analysis–a 6-inch deep stream and a 6-foot deep lake. Typical exposures were based on water concentrations in areas where the water surface is partially protected from drift by a vegetative canopy. Extreme exposures were based on water concentrations in an area with no protective canopy.

All herbicide treatments were assumed to be made via broadcast applications from aircraft. Aerial applications of herbicide have a significant potential to affect wildlife because these broadcast treatments may cover wide geographic areas encompassing many different types of terrestrial and aquatic habitats. Ground-based herbicide applications were not analyzed in the risk assessment because they have a lower potential to affect wildlife and aquatic species than a comparable aerial application of the same herbicide at the same application rate.

Nontarget Species Risk Analysis

The wildlife risk analysis compared the estimated acute doses to the representative wildlife species with the available hazard information on the most closely related species. To estimate the program's potential risk on wildlife, the doses calculated for each representative species were compared to toxicity data on laboratory test organisms (toxicity reference species). In many cases, however, toxicity information for the representative species was unavailable. Therefore, it was necessary to select a closely related species for which toxicity data were available.

The aquatic species risk analysis compared the estimated environmental concentration (EEC) with the laboratory-determined LC_{50} for the most closely related laboratory test species. The stream and lake scenarios were devised to represent the broadest possible range of aquatic habitat types in the Rocky Mountain regions. Risks were then calculated for two aquatic species for which toxicity data are generally available. Trout were chosen to represent cold-water fish in both streams and lakes and *Daphnia* were chosen to represent aquatic invertebrate species in both habitat types.

NONTARGET SPECIES RISK ASSESSMENT RESULTS

The results of the risk analysis indicate that potential risks to individual animals are low for most of the herbicides. Estimated doses for typical exposures result in a low risk from all herbicides and carriers. The application rates for several of the herbicides, coupled with extreme exposure estimates, may present moderate risks to individuals of some species. However, the estimated exposures exceed the LD_{50} (high risk) only under extreme exposure assumptions for the longtail vole during the use of 2,4-D, dicamba, tebuthiuron, and triclopyr, and for the belted kingfisher and the river otter during use of trifluralin.

The program's potential risk to representative aquatic species was determined by comparing the toxicity reference values for trout and aquatic invertebrates with the EECs for the typical and extreme stream and lake scenarios.

In the typical stream scenario, dichlobenil, diuron, and simazine may present a moderate risk to trout in streams. Triclopyr, trifluralin, diesel oil, and kerosene may present a high risk. Water concentrations of amitrole, atrazine, and dichlobenil in the typical stream scenario may present a moderate risk to aquatic invertebrates in streams while diuron, simazine, trifluralin, and diesel oil may present a high risk. In the extreme stream scenario, atrazine, bromacil, 2,4-D, dicamba, and picloram may present a moderate risk to trout while dichlobenil, diuron,

prometon, simazine, triclopyr, trifluralin, diesel oil, and kerosene may present a high risk. For aquatic invertebrates, clopyralid and dicamba may present a moderate risk and amitrole, atrazine, 2,4-D, dichlobenil, diuron, prometon, simazine, trifluralin and diesel oil may present a high risk.

In the typical lake scenario, diuron, triclopyr, and limonene may present a moderate risk to trout in lakes while trifluralin, diesel oil, and kerosene may present a high risk. For aquatic invertebrates in lakes, atrazine, dichlobenil, diuron, simazine, and trifluralin may present a moderate risk while diesel oil may present a high risk. In the extreme lake scenario, dichlobenil, diuron, and simazine may present a moderate risk to trout in lakes while triclopyr and kerosene may present a high risk. For aquatic invertebrates, atrazine and trifluralin may present a moderate risk and diuron, simazine, and diesel oil may present a high risk.

INFORMATION REGARDING HERBICIDES INCLUDED IN THE VEGETATION MANAGEMENT RISK ASSESSMENT - Continued

COMMON NAME	FAMILY	MAJOR TRADE NAMES	MANUFACTURER	MAJOR APPLICATIONS	MODE OF ACTION
MEFLUIDIDE	Ac	Embark, Vistar	PBI/Gordon	Suppresses Vegetative Growth and Seedhead Production in many Grass and Broadleaf Weeds and Woody plants (S)(FA)(NP)	Growth Regulator
METSULFURON METHYL	SU	Escort, Ally	Du Pont	Brush, Rangeland, Roadside, Non-crop Area Broadleaf Weed, Annual Grassy Weed (S)(FA)(P)	Inhibit Branch Chain Amino Acid Synthesis
PICLORAM	Py	Tordon, Grazon Access, Pathway	Dow-Elanco	Range Management, Noxious Weed, Site Prep Precommercial Thin, Conifer Release, Brush R-O-W, Non Crop Facility Sites (S)(FA)(P)(RA)(RU)	Growth Inhibitor
PROMETON	T	Pramitol, Primatol, Gesafram Prometon	Ciba-Geigy	Non-crop Area, Nonselective Preemergence and Postemergence that controls most Annual and Perennial Broadleaf and Grassy Weeds (NS)(RA)(P)	Photosynthesis Inhibitor
SIMAZINE	T	Princep, Aquazine, Pramitol Caliper	Ciba-Geigy Rhone Poulenc	Annual and Perennial Grass and Broadleaf Weeds, Algae, Nursery, Vegetation control in Non-Crop Areas, R-O-W (S)or(NS)(RA)(RU)	Photosynthesis Inhibitor
SULFOMETURON METHYL	SU	Oust	Du Pont	Site Prep, Conifer Release, Non-crop Area Preemergence and Postemergence control of many Annual and Perennial Grasses and Broadleaf Weeds (NS + S)(FA)(RA)(P)	Inhibit Branch Chain Amino Acid Synthesis
TEBUTHIURON	Ua	Graslan, Spike	Dow-Elanco	Rangeland, R-O-W, Non-crop Area, Woody Plants, Brush, Broadleaf Weeds (NS)(RA)(P)	Photosynthetic Inhibitor
TRICLOPYR	Py	Garlon 3A, Garlon 4, Grazon Grazon T, Turflon, Rely	Dow-Elanco	Rangeland, Non-crop Area, Woody Plants, Broadleaf Weeds and Brush, R-O-W, Non-irrigation Ditch Banks, Wildlife Openings (S)(FA)(NP)	Growth Regulator
TRIFLURALIN	D	Treflan, Trefanocide Elancolan	Dow-Elanco Monsanto American Cyanamid	Non-crop Area, Control many Grasses and Broadleaf Weeds, Preemergence, Should be Soil incorporated within 24 hours (S)(RA)(P)	Mitotic Disruptor

FAMILY SYMBOLS: A - Aliphatic, Ac - Acetamide, AT - Amino triazol, B - Benzonitrile, BA - Benzoic Acid, I - Imidazolinone, D - Dinitroamiline, Ph - Phynoxy, Py - Pyridine, SU - Sulfonylurea, T - Triazine, Ua - Urea, Uc - Uracil

OTHER SYMBOLS: (S) - Selective, (NS) - Nonselective, (FA) - Folier Absorbed, (RA) - Root Absorbed, (P) - Persistent in Soil, (NP) - Nonpersistent in Soil, (RU) - Restricted Use

SOURCE: HERBICIDE HANDBOOK of the Weed Science Society of America, Sixth Edition, 1989
PESTICIDE BACKGROUND STATEMENTS, Volume I, Agriculture Handbook No. 633
AGRICULTURAL CHEMICALS, Book II Herbicides, 1989-90 REVISION, W. T.Thomson
PESTICIDE FACT SHEETS, USDA Forest Service

REVISED 9/28/92

INFORMATION REGARDING HERBICIDES INCLUDED IN THE VEGETATION MANAGEMENT RISK ASSESSMENT

COMMON NAME	FAMILY	MAJOR TRADE NAMES	MANUFACTURER	MAJOR APPLICATIONS	MODE OF ACTION
AMITROLE	AT	Amizol, Weedazol, Amitrol-T Azalon, Cytrol Amitrol-T	Rhone-Poulenc Ag. Co.	Conifer Release, General Weed Control, Rangeland, R-O-W, Non-Crop Areas (NS)(FA)(NP)	Pigment Inhibitor
ATRAZINE	T	AAtrex, Atrazine Atratol	Ciba-Geigy Du Pont	Conifer Release, Site Prep, Rangeland Grass and Noxious Weed, Wildlife Habitat R-O-W (S)or(NS))(RA)(P)(RU)	Photosynthetic Inhibitor
BROMACIL	Uc	Hyvar, Krovar(+ Diuron) Bromax	Du Pont	Control Annual and Perennial Grasses, Broadleaf Weeds, Non-crop Areas (S)(RA)(P)	Photosynthetic Inhibitor
CHLORSULFURON	SU	Telar	Du Pont	Preemergence or early Postemergence for Annual Grasses and Broad leaf Weeds, Non-Crop Areas (S)(FA)(RA)(P)	Inhibit Branch Chain Amino Acid Synthesis
CLOPYRALID	Py	Reclaim, Stinger, Transline Curtail (+2,4-D)	Dow-Elanco	Site Prep, Rangeland, Non-Crop Areas, Broadleaf Annual and Perennial Weeds, and Woody Plants (S)(FA)(NP)	Not Clear
2,4-D	Ph	Many Trade Names are Used	Dow-Elanco Monsanto PBI/Gordon Etc.	Conifer Release, Noxious and Poisonous Weeds, Thinning, Timber Management, Wildlife Habitat, Rangeland, R-O-W, Aquatic weeds, Research and Engineering, Nursery, Recreation Mgmt., Firebreaks (S)(FA)(NP)	Growth Regulator
DICAMBA	BA	Banex, Banvel, Banvel D, Brush Buster, Trooper	Sandoz Monsanto	Site Prep, Thinning, Rangeland, Wildlife Habitat, Noxious Weed, General Weed Control, R-O-W, Non-Crop Area (S)(FA)(P)	Growth Regulator
DICHLOBENIL	B	Casoron, Barrier, Dyclomec, Norosac	PBI/Gordon Uniroyal	Acts on Growing Points and Root Tips, General Weed Control, Aquatic Weeds (S)(FA)(RA)(P)	Not Clear
DIURON	Ua	Karmex, Diuron DF	Du Pont Etc.	Non-crop Areas, General Weed Control, Selective at low Applied Rates (NS)(RA)(P)	Photosynthetic Inhibitor
GLYPHOSATE	A	Roundup, Rodeo, Accord, Landmaster(+ 2,4-D),Honcho	Monsanto	R-O-W, Conifer release, Aquatic weeds, Site Prep, Noxious weed, Facility Maintenance, (NS)(FA)(NP)	Inhibit Aromic Amino Acid Synthesis
HEXAZINONE	T	Velpar, Pronone	Du Pont	Site Prep, Conifer Release, Weeds, Grass, and woody plants, Nursery, X-mas tree Plantations, Food Crop, Pasture, R-O-W (S)or(NS)(FA)(RA)(P)	Photosynthetic Inhibitor
IMAZAPYR	I	Arsenal, Chopper, Contain	American Cyanamid	Conifer Release, Site Prep, R-O-W, Non-Crop Area, Annual, Perennial Weeds (NS)(FA)(RA)(P)	Inhibit Branch Chain Amino Acid Synthesis

-- Continued --

Jim Brown
R-8

USFS Forest Pest Management
National Steering Committee - Vegetation Management
Report By Jim Brown, Southern Region
December 1992, Davis, CA

The Southern Region has the Service's largest herbicide program, with 65,000 acres treated in FY 1992, using just over 66,000 pounds of active ingredient. This is a reduction to about 78% of our FY 1991 program acres, reflecting reduced timber harvest acreage, and perhaps some increase in bias against use by individual managers. The majority of the applications were used in silviculture for site preparation and release; wildlife habitat management and right-of-way maintenance account for most of the non-silvicultural applications. The Southern Region has a small range management program, which accounts for little herbicide use.

Although we have had authority for over a year to resume aerial application of herbicides under limited conditions, our program at present is still 100% ground application. This is due primarily to management emphasis on selective herbicide treatments to maintain biological diversity. While hardwood control is important in the management of southern pines, some hardwood species are highly important to wildlife, and some are also valuable timber species. Broadcast applications which control hardwoods are thus often undesirable, and with the increasing emphasis on uneven-aged silvicultural systems, it is unlikely that we will see a resurgence of aerial applications in the future. We currently are aware of only one proposal for aerial application during the coming year, and approval for it will hinge on whether the U.S. Fish & Wildlife Service decides that it may jeopardize habitat for the Red-cocaded Woodpecker, a Threatened species.

We feel that herbicides are extremely important management tools in the South. Because of our warm climate and abundant moisture, growing conditions are ideal, and we tend to have a lot of vegetative competition to deal with. Without herbicides, whether you use chainsaws, bulldozers, or goats, treating undesirable vegetation just produces more sprouting, which requires repeated treatments. This is both expensive and inefficient, and our Risk Assessment has shown that it is also more dangerous to workers than herbicide application. As we move toward "Ecosystem Management," it appears that our need for selectively applied herbicides will increase. Many of our ecosystems are adapted to fire, and fire is no longer acceptable on a landscape scale; in fact, it is often unacceptable even on a very small scale. In many cases, herbicide use is the only available substitute for fire to maintain these ecosystems and the species dependent upon them. Unfortunately, we recognize that herbicides are a political hot potato, and we are very concerned over the lack of support for the program at the Chief's level. An administrative decision to "drop herbicides," such as the decision regarding clearcutting announced in the Chief's June 4 letter, would be devastating to both silviculture and wildlife programs in the South. We strongly urge the WO FPM staff to uphold the program.

A quick run-down of the herbicides in our program is as follows:

CLOPYRALID - We have extracted the necessary data from the "Western Regions" risk assessment, and hope to complete an amendment to our Vegetation Management

EISs in 1993 to add this chemical to our toolbox. Its primary purpose will be to replace picloram in kudzu control; it is a highly selective chemical which essentially controls only legumes and composites, and can thus be used against kudzu in established stands of trees without damaging the trees themselves. Experimental work with the product has been very promising so far.

DICAMBA - Although still available, no one in the region is now using this chemical. Its soil activity, lack of selectivity, and strong offensive odor have rendered it less desirable than other products, and we see no current need to use it.

FOSAMINE AMMONIUM - This is a minor-use product, primarily employed for maintaining rights-of-way and the edges of wildlife openings, where it is desirable to prune off projecting branches without killing entire trees. We are looking at possible uses as a pruning agent to improve hardwood stem quality, but the chemical is generally not used for silviculture.

GLYPHOSATE - This chemical is fairly widely used both in silviculture and in wildlife habitat management. It is employed either by injection or as a foliar spray; timber industries throughout the South use it as an aerial-applied foliar spray late in the growing season for control of hardwoods in intensively managed pine plantations. Its low mamalian toxicity and lack of soil activity make it an ideal choice in many situations. We have contracted a worker exposure study of glyphosate through Georgia Tech. While we have not received the final report of this study, the exposure data indicates a much lower risk for the product than our modeling predicted; average margins of safety (MOS) achieved by the workers in the study were in the range of 168,000, as compared to a predicted MOS of 600. Copies of the study report will be made available when received.

HEXAZINONE - We continue to use a fair amount of this product in pine management. It has been particularly valuable for hardwood control in longleaf pine stands, where hardwoods not only compete for moisture, but also interfere with development of the grass understory which is a vital part of the fire regime to which longleaf pine is adapted. The mobility of Hexazinone in soil has been a concern in many areas, and we generally do not use it in mountainous terrain. In addition, the state of Florida passed legislation this year which prohibits soil applications of herbicides in any watershed recharge area, and this will curtail most future uses of hexazinone in that state.

IMAZAPYR - This is one of our newer tools, and appears very promising in pine management. Although it is soil-active, we employ it primarily as a directed foliar spray at very low rates, where we can selectively control or release individual hardwoods in pine stands. Recent research has shown very good control of hardwoods using a low-intensity injection technique with this product, and we are moving toward imazapyr as a replacement for some of our tryclopyr injection in future work. We have not recommended soil applications of imazapyr because the chemical is extensively used in this way by industry, and we are concerned that we not be implicated if any soil or water contamination should occur. Soil applications also are non-selective, and do not allow us to retain desirable hardwoods.

PICLORAM - Use of this product is essentially confined to kudzu control, and we hope to replace it with clopyralid in the near future. It is a very low-risk

product in terms of human health; but its soil activity, mobility, and extreme toxicity to many economically important plant species dictates that we avoid it wherever possible.

SULFOMETURON METHYL - Our primary use of this product is to control grass around longleaf pine seedlings. This pine has a unique early growth form called the "grass stage," in which the seedling produces a whorl of needles just above the root collar, looking very much like a clump of grass, and does not initiate height growth until it has developed a certain level of root system and energy reserves. Moisture competition from grasses inhibits seedling development, and can thus prevent the initiation of height growth for several years. Spot applications of sulfometuron methyl around longleaf pine seedlings, either pre-plant or as a spot-over after planting, reduce grass competition enough to allow pine seedlings to initiate height growth after the first growing season, thus greatly enhancing stand development. Sulfometuron methyl has also been shown to improve growth on loblolly pine with spot or band treatments, but is not cost-effective in broadcast applications.

TEBUTHIURON - We do not currently use this chemical, although it could be used for range management on drier sites such as the national grasslands in Texas. Because of concerns over long half-life and potential for off-site migration, (and for human health in the backpack applied scenarios), any use of this product requires prior approval by the Regional Forester.

TRICLOPYR - This product is our most widely used herbicide, and in fact accounted for over 75% of our total program acres in 1992. This is of some concern to us for several reasons: 1) If registration were to be cancelled or suspended for any reason, it could cripple our program; 2) We don't want our silviculturists to become accustomed to prescribing the same treatments in every situation, but to always look for the best product for the job at hand; and 3) Although tryclopyr is an excellent tool, it does have some limitations, and is notoriously weak in controlling stump sprouts of maple species. We have used tryclopyr amine (Garlon 3A) as an injection chemical, and expect to replace it in many applications with imazapyr. Tryclopyr ester (Garlon 4) will continue to see wide use as a basal bark treatment, using the "streamline" application methods developed by Max Williamson.

The mixture used in the streamline method has gone through an interesting evolution process. We used to apply it at 20% strength in a mixture with fuel oil and Cide-Kick adjuvant, but found that the fuel oil actually was more dangerous to the applicators that the herbicide. It also had some undesirable effects on the treated vegetation, reducing the effectiveness of the herbicide. We have switched from fuel oil to light mineral oil (JLB Oil Plus), which is more expensive, but much lower in risk. Max Williamson has encouraged the chemical companies to continue development in this area, and JLB Chemical has just introduced a vegetable oil carrier ("Improved JLB Oil Plus") which is available through GSA at the same price as their mineral oil. We are very pleased with this product. DowElanco is also working on a vegetable oil substitute for the kerosene carrier in Garlon 4.

A worker exposure study on triclopyr has been completed by Georgia Tech, and copies will be made available to other Regions and the WO. The study shows that an average MOS of about 150 was achieved, fairly close to the VM FEIS model prediction. However, not all workers achieved the minimum acceptable MOS

Priorities for forestry herbicide application technology research

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ABSTRACT

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A survey was conducted to determine research priorities for forest herbicide application technology research. It was sent to persons, primarily in Canada and the U.S., with an interest in the topic (users, applicators, researchers, regulators). Respondents indicated support for both aerial and ground application technology research. The top ten priorities of all respondents combined for future herbicide application technology research were: (1) determine appropriate scientifically-based buffer zones, (2) develop technology to allow the same efficacy with reduced active ingredient, (3) develop technology to allow the same efficacy with reduced spray volume, (4) determine the optimum drop size with regard to efficacy and drift, (5) improve rainfastness of herbicides, (6) determine the effect of atmospheric stability and wind on herbicide drift, (7) determine the dose-response curve for environmental impact vs herbicide deposit, (8) determine the effect of temperature and relative humidity on deposit/efficacy, (9) develop atomizers capable of emitting a narrow drop size spectra regardless of aircraft speed, (10) determine the effect of temperature and relative humidity on drift. The problem, "Determine how to develop public support for aerial application of

herbicides in forestry", although not really an application technology problem ranked number one for Canadian users and aerial applicators, and number four for U.S. users.

Introduction

Approximately 200,000 ha of Canada's forest lands are treated with herbicide each year (Campbell 1990). A number of groups with significant user input have produced lists of application technology problems (e.g., Barry 1990a, 1990b; Buckner 1988; Wiesner 1990) which indicates a need for research in this area. Most of the problems relate to a desire to improve efficacy, increase application equipment productivity, decrease costs, and decrease off-target impact.

The Improved Pesticide Applications Working Group of the Forest Pest Management Institute unanimously agreed in the fall of 1990 that there was a need to set priorities for forest pesticide application technology research. In addition, members of the Working Group felt that there was insufficient coordination of the research being done by different agencies across North America and decided that a survey of the various stakeholders should be the first step in addressing these problems. Respondents would be asked to prioritize application technology problems as candidates for research, and to indicate what research areas they were currently involved in or would be willing to become involved in. This paper reports on the herbicide application technology portion of the survey.

Methods

Survey content

A number of committees and groups have prepared lists of application technology problems requiring research. The items that respondents were asked to prioritize in our survey were compiled from the following sources: Spray Efficacy Research Group (Wiesner 1990); National Research Council of Canada Associate Committee on Agricultural and Forestry Aviation (Buckner 1988; Green 1988; McCooeye 1990); USDA Forest Service National Steering Committees for Aerial Application of Pesticides (Barry 1990a, 1990b); Forest Engineering Research Institute of Canada (J. Dunnigan, personal communication); Improved Pesticide Applications Working Group of the Forest Pest Management Institute (personal communications).

Respondents were asked if they placed a higher priority on research to improve ground or aerial herbicide application technology. Then they were asked to give each of the 59 herbicide application technology problems (see appendix) a priority from 1 (high) to 5 (low) for future research. Problems for which the respondent felt there were already adequate answers were to be rated as 6. The rationale was that if a

problem was generally ranked as a high priority for research, and viewed by some respondents as being adequately answered, it would indicate a need for better technology transfer.

If any of the items represented areas of research in which the respondent was currently involved, or would like to become involved, he/she was asked to check mark it and elaborate on the nature of his/her potential involvement. This was intended to facilitate the establishment of more collaborative research and minimize unnecessary duplication of effort. As application technology research often requires resources well beyond those of individual agencies, research establishments, users, manufacturers and applicators were encouraged to become involved in items of their choice.

Target audience

The survey targeted a variety of stakeholder groups with an interest in forest pesticide application: forest managers/forest pest managers, commercial applicators, pesticide regulators, researchers, pesticide manufacturers and application equipment manufacturers. The survey was weighted towards Canadian responses but researchers, and state and federal forest pest management staff in the United States were also

surveyed. The basic mailing list was that developed by the Associate Committee on Agricultural and Forestry Aviation in the course of producing symposia in 1987 and 1990. It was supplemented by membership lists of the Canadian Association of Pest Control Officials and the Canadian Aerial Applicators' Association, and lists of contacts possessed by researchers at the Forest Pest Management Institute. Forest pest management staff in each province supplied names of forest management personnel who had experience in pesticide application. The USDA Forest Service supplied the names of state and federal forest pest management staff. No attempt was made to obtain a random sample of each of the target groups. Surveys were sent to persons considered to be knowledgeable and interested in forest pesticide application within each group. A total of approximately 1500 surveys were sent out. No followup requests were made - the results represent surveys returned following the initial mailing.

Data analysis

Information from the returned surveys was entered into a dBASE IV database. Portions of this database were transferred to Lotus 1-2-3 for calculations. The priorities for each item were averaged and then

ranked, with the lowest average being the highest priority. Unanswered questions were treated as missing values rather than zeros. The "6" values were included in the averages on the basis that if a problem has already been solved it should have the lowest priority of all.

Results and discussion

Of the 1500 surveys sent out, 297 were returned. Two hundred twenty six responded to the herbicide portion of the questionnaire. One hundred seventy five of the herbicide responses came from Canada, 46 from the United States and five from other countries. The distribution of Canadian and U.S. responses among the various respondent categories are shown in Table 1.

Although respondents were asked to indicate which respondent category they belonged to, some difficulty was encountered in making final assignments. Some persons listed several categories. In these cases, we chose what we considered to be the most important single category. Thus no person's response was included in the results for more than one category. A considerable number of respondents from forest management agencies listed themselves as regulators because they had some control over the activities of timber companies operating

on Crown land. In this paper, the regulator category includes only those persons working for an agency whose sole purpose is pesticide registration or regulation.

Table 2 shows the relative importance users and researchers in the U.S. and Canada place on ground vs aerial application technology research. Fifty-four per cent of the Canadian users felt that a higher priority should be placed on research to improve aerial application technology while 35 per cent felt a higher priority should be placed on ground application technology research. This is consistent with the fact that three quarters of the herbicide used for forest management in Canada is applied aerially (Campbell 1990). Although U.S. responses indicated a strong preference for ground application technology research (users - 53%, researchers - 62%), it is not possible to determine whether differences between Canadian and U.S. responses are significant because of the low number of responses.

In Canada, almost all mobile ground sprayers developed specifically for forestry have been designed by contractors and forest managers. Government and university researchers have had little involvement. It was because of the lack of information on the topic that the Forest Engineering Institute of Canada recently completed a review which identified the important characteristics of mobile ground spraying

systems and described the principal systems used in eastern Canada (Desrochers and Dunnigan 1991). Researchers must take a more active role in this area if their work is to remain relevant to the needs of the users.

Tables 3 to 8 give the top ten herbicide application technology research priorities for Canadian users, aerial applicators, researchers and regulators, and for U.S. users and researchers. The problem, "Determine how to develop public support for aerial application of herbicides in forestry", although not really an application technology problem ranked number one for Canadian users and aerial applicators, and number four for U.S. users. Clearly, the people actually applying herbicides see negative public opinion as the most important limiting factor. Technical arguments have not convinced the public that herbicide use is acceptable. New approaches for responding to public concern need to be developed and should involve input from the social sciences along with that from users and forest researchers. There are some differences in the priorities of the various groups but most can be grouped into several categories: reduce costs (reduced active ingredient, reduced spray volume); increased efficacy (improved rainfastness, optimum drop size, best atomizer for different situations, effect of humidity on efficacy,

improved pilot guidance); reduced environmental impact (buffer zones, meteorological effects on drift, non-target dose-response curves).

Table 9 gives the top ten priorities overall based on equal weighting of each of four respondent categories (forestry users, researchers, Canadian aerial applicators and Canadian regulators). These are the items most likely to be addressed because, if the researchers see them as priorities, they will want to work on them, and if the users see them as priorities, the researchers will be more likely to get funding and approval to work on them.

In spite of the significant proportion of respondents who placed a higher priority on ground application research, relatively few of the ground application problems made it into the top ten priorities for individual respondent groups and none made it into the overall top ten. This apparent inconsistency probably arose because most forestry herbicide applications are made aerially (Campbell 1990), but many forest managers feel that ground application may be their only option in the future (as evidenced by the high priority they placed on gaining public support for aerial application [Table 3]). For this reason, the top ten ground application problems were determined separately and listed in Tables 10 and 11. The emphasis in these priorities is on overcoming the difficulties of operating on forest terrain (less likely to spill when tips,

less likely to tip, speed control, speed regulated flow control, operator guidance). Both user groups put a higher priority on designing a sprayer that is less likely to spill when it tips over than to design a sprayer less likely to tip over. Conversations with forest sprayer operators indicate that these priorities reflect the belief that upsets are inevitable.

The "6" ranking did not clearly define which problems had already been solved. When the responses of the U.S. and Canadian researchers were pooled, there were only seven out of the 59 problems which at least one researcher did not feel had already been solved and the highest number of "6"s was 11 out of 35.

The followup of the survey will focus on the users' needs and will include several steps:

1. Researchers who ranked problems as "6" (solved) will be asked to provide scientific information to justify their claim. This will be reviewed by the Forest Pest Management Institute Improved Pesticide Applications Working Group, the Spray Efficacy Research Group (SERG)[1], and the USDA

[1] The Spray Efficacy Research Group is a voluntary association of forest management, regulatory and research agencies interested in the application of forest pesticides. The aim of SERG is to improve the application technology associated with forest pesticide use. SERG aims to provide a multidisciplinary scientific approach to applications research, in the context of the needs and priorities of provincial and industrial forest managers (Spray Efficacy Research Group Terms of Reference, unpublished 1992).

Forest Service National Steering Committee for Managing Vegetation on Forest and Range Lands (USDAFSNSCVMFRL) to determine if there is technology which could be transferred, and if further research is required.

2. If there is technology to be transferred, it will be necessary to convert the scientific information into a form suitable for users. Assuming funding for this effort can be obtained, drafts of the technology transfer information on each problem will be sent to users who had placed a high priority on that particular problem. They will be asked to specify whether the information solves the problem either partially or completely from their perspective, and if not, why not. This feedback loop will indicate whether the technology transfer needs to be improved or whether more research is required. The process will begin with the items ranked highest by the users. Since even the lowest ranked problems were a priority for some users, an effort will be made to ensure the technology transfer program is completed for all problems.

Examples of several candidates for technology transfer are:

a) "Develop mixing and loading equipment which reduce worker exposure to herbicide" was ranked six by Canadian regulators, and it was ranked three and six in the ground application technology problems by Canadian and U.S. users respectively. Closed mixing and loading systems are available commercially.

b) "Develop a flow control which is regulated by sprayer ground speed" was ranked eight in the Canadian users ground application technology priority list. An inline herbicide injection system is described in a USDA Forest Service ground applications manual (Miller and Mitchell 1988).

c) "Develop equipment which can monitor application rate and spray mix remaining in the tank" was ranked ten in the Canadian and nine in the U.S. users ground application technology priority lists. Computerized monitoring systems capable of doing this are commercially available.

3. Where a need for research has been indicated, projects to address the gaps will be coordinated through the research

consortia (SERG and USDAFSNSCVMFRL)[2]. Respondents who indicated interest in involvement in research on specific problems will be invited to participate in planning and execution of projects on these problems. As with the technology transfer, the problems ranked highest by the users will be addressed first.

4. Although refinement of spray models was not a high priority for users, the nature of many of the users' priority problems, and the degree of their interaction, are such that models must be used to address them. For this reason, improvement of the models should have a high priority.

5. The problem of "developing public support for aerial application of herbicides" is not one which can be addressed by scientific research. For this reason, it will be referred to the Forest Pest Management Caucus (formerly called the Forestry Pesticides Caucus)[3], the Forest Pest

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[2] The strength of these research consortia lies in their multidisciplinary approach - which is essential to finding solutions to these complex problems.

[3] "The Forestry Pesticides Caucus is a national body of pest management experts representing forest industry trade associations, provincial and federal governments, academia, the forestry profession, woodlot owners, and vegetation managers." It was formed to coordinate the participation of the forest sector in the Pesticide Registration Review and to develop an economic benefit analysis from a forest protection perspective. (Can. Pulp Paper Assoc., For. Protect. Commun., Aug 1989)

Control Forum[4], and other groups having a more public focus .

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[4] The Forest Pest Control Forum is held under the aegis of Forestry Canada to provide the opportunity for representatives of provincial and federal governments and private agencies to review and discuss forest pest control operations in Canada and related research (Moody 1992).

and Agriculture), John Dojack and Richard Westwood (Manitoba Natural Resources), Jerry Gavin (Prince Edward Island Department of Energy and Forestry), Bud Irving (Canadian Aerial Applicators Association), Jacques LaRue (REXFOR), and Margaret McCooeye (Associate Committee on Agricultural and Forestry Aviation) for supplying mailing lists or distributing surveys within their organizations; and the 226 people who took time to fill out a survey form.

References

Barry, J. W. (Editor). 1990a. National Steering Committees for Aerial Application of Pesticides, Report no. 1. USDA Forest Service, Forest Pest Management, Davis, CA. FPM 90-3.

Barry, J. W. (Editor). 1990b. Second report, National Steering Committee for Application of Pesticides - Vegetation Management. USDA Forest Service, Forest Pest Management, Davis, CA. FPM 90-4.

Buckner, C. H. (Editor). 1988. The aerial application of herbicides in forestry: proceedings of a workshop sponsored by the Associate Committee on Agriculture and Forestry Aviation, and the Canadian Forestry Service. National Research Council of Canada, Ottawa.

Campbell, R.A. 1990. Herbicide use for forest management in Canada: where we are and where we are going. For. Chron.: 66: 355-360.

Desrochers, L., and Dunnigan, J. 1991. Mobile sprayers for ground application of herbicides. Special Rep. SR-79. Forest Engineering Research Institute of Canada, Pointe Claire, PQ.

Green, G.W. (Editor). 1988. Recommendations arising from the Associate Committee on Agricultural and Forestry Aviation symposium on the aerial application of pesticides in forestry held in Ottawa in October 1987. National Research Council of Canada, Ottawa.

McCooeye, M. (Editor). 1990. Summary of the Associate Committee on Agricultural and Forestry Aviation held in Winnipeg in October 1990. National Research Council of Canada, Ottawa.

Miller, J. H., and Mitchell, R. J. 1988. A manual on ground applications of forestry herbicides. Management Bulletin R8-MB 21. USDA Forest Service, Atlanta, GA.

Moody, B.H. (Editor). 1992. Report of the Nineteenth Annual Forest Pest Control Forum, 19-21 Nov. 1991, Ottawa, ON. Forestry Canada, Ottawa, ON.

Wiesner, C. J. (Editor). 1990. Spray Efficacy Research Group draft five year plan. Spray Efficacy Research Group, Fredericton, NB.

Table 1. Number of Canadian and U.S. responses to the herbicide application technology survey in each respondent category

	No. of responses	
Respondent category	Canada	U.S.
Forestry herbicide users[a]	94	15
Researchers	26	19
Aerial applicators	23	3
Pesticide manufacturers	10	4
Provincial pesticide regulators	7	
Federal pesticide regulators	5	1
Ground applicators	4	1
Non-forestry users	3	2
Equipment manufacturers	2	1
Other	1	
Total	175	46

[a]For Canada - provincial forest management and forest pest management staff, and timber company staff. For U.S. - federal and state forest pest management staff

Table 2. Percentage of respondents who placed a higher priority on aerial vs ground application technology research

	% of respondents			
	Canada		U.S.	
Priority	Users[a]	Researchers	Users[b]	Researchers
Aerial	54	62	40	26
Ground	35	27	53	64
Equal	1	8	7	5
No opinion	10	3	0	5

[a]Provincial forest management and forest pest management staff, and timber company staff

[b]Federal and state forest pest management staff

Table 3. The top ten herbicide application technology research priorities for Canadian users

1. Determine how to develop public support for aerial application of herbicides in forestry.
2. Develop application technology to allow the same efficacy with reduced ai/ha.
3. Determine appropriate, scientifically-based buffer zone widths required to prevent significant environmental impact in sensitive areas.
4. Develop application technology to allow the same efficacy with reduced total spray volume/ha.
5. Improve rainfastness of herbicides.
6. Determine the effect of atmospheric stability and wind speed on herbicide off-target movement.
7. Develop improved operational spray block and swath marking techniques to guide the spray pilot (i.e., assist him to position the aircraft accurately in relation to the previous swath, and tell him when to boom on and off).
8. Determine the effect of temperature and relative humidity at time of application on herbicide off-target movement.

9. Determine the influence of temperature and relative humidity at time of application on herbicide deposition/efficacy.
10. Determine the optimum drop size for the various herbicides to provide maximal efficacy without unacceptable off-target movement.

Table 4. The top ten herbicide application technology research priorities for Canadian aerial applicators

1. Determine how to develop public support for aerial application of herbicides in forestry.
2. Improve rainfastness of herbicides.
3. Determine if wet foliage reduces herbicide efficacy.
4. Determine the effect of rainfall after application on herbicide efficacy.
5. Compare the numerous different atomizers which are currently being used for aerial herbicide application in terms of efficacy and off-target movement.
6. Determine the optimum drop size for the various herbicides to provide maximal efficacy without unacceptable off-target movement.
7. Determine if Micronair atomizers provide better herbicide efficacy than hydraulic nozzles without producing unacceptable off-target movement.
8. Determine if efficacy on hard-to-control weeds (e.g., red maple) can be increased by altering application parameters.

9. Determine the effect on non-target species (plant and animal) of deposit rates from maximum label rate to the no-effect rate. Determine how long the effects last.

10. Develop application technology to allow the same efficacy with reduced total spray volume/ha.

Table 5. The top ten herbicide application technology research priorities for Canadian researchers

1. Develop application technology to allow the same efficacy with reduced ai/ha.
2. Develop application technology to allow the same efficacy with reduced total spray volume/ha.
3. Improve rainfastness of herbicides.
4. Determine appropriate, scientifically-based buffer zone widths required to prevent significant environmental impact in sensitive areas.
5. Determine how to develop public support for aerial application of herbicides in forestry.
6. Determine the effect on non-target species (plant and animal) of deposit rates from maximum label rate to the no-effect rate. Determine how long the effects last.
7. Determine if efficacy on hard-to-control weeds (e.g., red maple) can be increased by altering application parameters.
8. Determine the optimum drop size for the various herbicides to provide maximal efficacy without unacceptable off-target movement.

9. Develop improved operational spray block and swath marking techniques to guide the spray pilot (i.e., assist him to position the aircraft accurately in relation to the previous swath, and tell him when to boom on and off).

10. Compare efficacy of different ground sprayers (e.g., Boomjet, air blast, Radiarc).

Table 6. The top ten herbicide application technology research priorities for Canadian regulators

1. Determine appropriate, scientifically-based buffer zone widths required to prevent significant environmental impact in sensitive areas.
2. Develop a model which can be used in a hand-held computer in the field to make spray/no-spray recommendations based on temperature, relative humidity, wind direction, wind speed, atmospheric stability and distance from values to be protected from spray.
3. Develop atomizers capable of emitting a spray cloud with narrow drop size spectra in optimal drop size ranges, regardless of aircraft speed.
4. Compare the numerous different atomizers which are currently being used for aerial herbicide application in terms of efficacy and off-target movement.
5. Develop application technology to allow the same efficacy with reduced ai/ha.
6. Develop mixing and loading equipment which reduce worker exposure to herbicide.

7. Determine the effect on non-target species (plant and animal) of deposit rates from maximum label rate to the no-effect rate. Determine how long the effects last.

8. Determine the effect of atmospheric stability and wind speed on herbicide off-target movement.

9. Improve methods of herbicide accountancy.

10. Develop a metering device for backpack sprayers when used for making spot applications of simazine.

Table 7. The top ten herbicide application technology research priorities for U.S. users

1. Determine appropriate, scientifically-based buffer zone widths required to prevent significant environmental impact in sensitive areas.
2. Develop application technology to allow the same efficacy with reduced total spray volume/ha.
3. Determine the optimum drop size for the various herbicides to provide maximal efficacy without unacceptable off-target movement.
4. Determine how to develop public support for aerial application of herbicides in forestry.
5. Improve rainfastness of herbicides.
6. Develop improved operational spray block and swath marking techniques to guide the spray pilot (i.e., assist him to position the aircraft accurately in relation to the previous swath, and tell him when to boom on and off).
7. Determine the effect of atmospheric stability and wind speed on herbicide off-target movement.

8. Design ground sprayer which can operate on currently unoperable terrain (e.g., sites currently operable only in winter or sites with very uneven terrain).

9. Determine the effect on non-target species (plant and animal) of deposit rates from maximum label rate to the no-effect rate. Determine how long the effects last.

10. Develop ground sprayers less subject to spillage following an upset.

Table 8. The top ten herbicide application technology research priorities for U.S. researchers

1. Develop application technology to allow the same efficacy with reduced ai/ha.
2. Develop application technology to allow the same efficacy with reduced total spray volume/ha.
3. Determine appropriate, scientifically-based buffer zone widths required to prevent significant environmental impact in sensitive areas.
4. Determine the optimum drop size for the various herbicides to provide maximal efficacy without unacceptable off-target movement.
5. Determine how to develop public support for aerial application of herbicides in forestry.
6. Improve rainfastness of herbicides.
7. Determine the effect of atmospheric stability and wind speed on herbicide off-target movement.
8. Improve methods of herbicide accountancy.

9. Verify the AGDISP, WEIHS, PKBW and FSCBG spray models for herbicide applications to at least 1 km downwind using definitive field experiments. Fill necessary data gaps.

10. Compare the numerous different atomizers which are currently being used for aerial herbicide application in terms of efficacy and off-target movement.

Table 9. The top ten herbicide application technology research priorities for four respondent groups combined[a]

1. Determine appropriate, scientifically-based buffer zone widths required to prevent significant environmental impact in sensitive areas.
2. Develop application technology to allow the same efficacy with reduced ai/ha.
3. Develop application technology to allow the same efficacy with reduced total spray volume/ha.
4. Determine the optimum drop size for the various herbicides to provide maximal efficacy without unacceptable off-target movement.
5. Improve rainfastness of herbicides.
6. Determine the effect of atmospheric stability and wind speed on herbicide off-target movement.
7. Determine the effect on non-target species (plant and animal) of deposit rates from maximum label rate to the no-effect rate. Determine how long the effects last.
8. Determine the influence of temperature and relative humidity at time of application on herbicide deposition/efficacy.

9. Develop atomizers capable of emitting a spray cloud with narrow drop size spectra in optimal drop size ranges, regardless of aircraft speed.

10. Determine the effect of temperature and relative humidity at time of application on herbicide off-target movement.

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[a]Priorities were calculated for each of four groups (Canadian + U.S. forestry users, Canadian + U.S. researchers, Canadian aerial applicators, Canadian regulators). These priorities were then averaged thereby giving each group equal weight in setting the priorities in the table.

Table 10. The top ten herbicide ground application technology research priorities for Canadian users

1. Develop ground sprayers less subject to spillage following an upset.
2. Develop a guidance or marking system for ground sprayers to ensure that successive swaths are correctly spaced.
3. Develop mixing and loading equipment which reduce worker exposure to herbicide.
4. Develop a good speed control system for ground sprayers.
5. Develop safety standards for the construction of ground sprayers.
6. Develop ground application systems which can operate in higher wind conditions.
7. Design ground sprayer which can operate on currently unoperable terrain (e.g., sites currently operable only in winter or sites with very uneven terrain).
8. Develop a flow control which is regulated by sprayer ground speed.
9. For the various ground sprayers, determine the best orifices for optimal application.
10. Develop equipment which can monitor application rate and spray mix remaining in tank.

Table 11. The top ten herbicide ground application technology research priorities for U.S. users

1. Design ground sprayer which can operate on currently unoperable terrain (e.g., sites currently operable only in winter or sites with very uneven terrain).
2. Develop ground sprayers less subject to spillage following an upset.
3. Design ground sprayer which is less prone to tip over.
4. Develop a high clearance ground sprayer., i.e., one capable of straddling a row(s) of trees.
5. Develop a good speed control system for ground sprayers.
6. Develop mixing and loading equipment which reduce worker exposure to herbicide.
7. Develop a guidance or marking system for ground sprayers to ensure that successive swaths are correctly spaced.
8. Develop a metering device for backpack sprayers when used for making spot applications of simazine.
9. Develop equipment which can monitor application rate and spray mix remaining in tank.
10. Develop safety standards for the construction of ground sprayers.

Appendix. Complete list of herbicide application technology problems listed in the survey and their ranking by several respondent groups

		CU[a]	CA[a]	CR[a]	CG[a]	UU[a]	UR[a]	CO[a]
A.	Develop improved operational spray block and swath marking techniques to guide the spray pilot (i.e., assist him to position the aircraft accurately in relation to the previous swath, and tell him when to boom on and off).	8	34	10	38	7	27	19
B.	Develop a system which would record spray aircraft performance in relation to specific points within a spray block (air speed, ground speed, height, spray mix flow to boom, wind speed, wind direction, booms on or off, temperature, boom pressure, atomizer RPM, LORAN "C" or GPS position and relative humidity). List any other information which you would like to see recorded:	26	24	43	48	55	29	38
C.	Develop an altimeter which can register height above the canopy or the ground (as opposed to altitude above sea level which is what normal [barometric] altimeters measure).	56	58	57	55	16	50	58
D.	Develop a flow control which is regulated by aircraft ground speed.	30	18	35	44	19	28	28

		CU[a]	CA[a]	CR[a]	CG[a]	UU[a]	UR[a]	CO[a]
E.	Develop operational field equipment for measuring the meteorological parameters necessary for spray/no-spray decisions.	47	29	29	13	48	23	26
F.	Develop a practical system for aircraft to record temperature profiles and identify inversions.	36	31	37	32	56	43	40
G.	Determine the effect of atmospheric stability and wind speed on herbicide deposition/efficacy.	12	11	28	25	13	13	14
H.	Determine the effect of atmospheric stability and wind speed on herbicide off-target movement.	7	17	24	8	8	8	7
I.	Determine the influence of temperature and relative humidity at time of application on herbicide deposition/efficacy.	10	12	18	22	21	15	10
J.	Effect of temperature and relative humidity at time of application on herbicide off-target movement.	9	16	32	12	14	12	12
K.	Determine if wet foliage reduces herbicide efficacy.	29	3	22	47	54	17	21
L.	Determine the effect of rainfall after application on herbicide efficacy.	25	4	31	52	45	14	24

		CU[a]	CA[a]	CR[a]	CG[a]	UU[a]	UR[a]	CO[a]
M.	Improve rainfastness of herbicides.	5	2	3	29	6	6	5
N.	Determine the difference in efficacy between morning vs evening herbicide applications.	27	21	36	45	24	25	31
O.	Develop specifications for optimum nozzle location for all nozzle types on all types of spray aircraft.	32	20	51	17	22	37	25
P.	Develop atomizers capable of emitting a spray cloud with narrow drop size spectra in optimal drop size ranges, regardless of aircraft speed.	18	23	13	3	26	32	11
Q.	Verify the AGDISP, WEIHS, PKBW and FSCBG spray models for herbicide applications to at least 1 km downwind using definitive field experiments. Fill necessary data gaps.	55	39	14	20	34	10	30
R.	Develop a model which can be used in a hand-held computer in the field to make spray/no-spray recommendations based on temperature, relative humidity, wind direction, wind speed, atmospheric stability and distance from values to be protected from spray.	22	25	19	2	17	21	16

		CU[a]	CA[a]	CR[a]	CG[a]	UU[a]	UR[a]	CO[a]
S.	Develop a distribution model for aerial application of non-liquid herbicides.	50	40	44	34	46	52	47
T.	Improve methods of herbicide accountancy.	35	32	17	9	27	9	18
U.	Determine off-target movement of granular herbicides (dust rather than the granules themselves).	51	36	25	14	42	19	29
V.	Determine uniformity of granular deposit across aerial swath for different applicators (DuPont ULW applicator, ISOLAIR) and different aircraft.	53	35	21	21	50	30	36
W.	Compare the numerous different atomizers which are currently being used for aerial herbicide application in terms of efficacy and off-target movement.	37	5	45	4	53	11	17
X.	Determine if Micronair atomizers provide better herbicide efficacy than hydraulic nozzles without producing unacceptable off-target movement.	24	7	33	37	43	33	22
Y.	Develop application technology to allow the same efficacy with reduced ai/ha.	2	13	1	5	12	1	2

		CU[a]	CA[a]	CR[a]	CG[a]	UU[a]	UR[a]	CO[a]
Z.[b]	Determine whether low volume aerial herbicide applications (11 L/ha) as currently practiced provide adequate efficacy without producing unacceptable off-target movement.	6	10	2	16	4	7	3
AA.[b]	Develop application technology to allow the same efficacy with reduced total spray volume/ha.	4	26	4	11	2	2	6
AB.	Determine the optimum drop size for the various herbicides to provide maximal efficacy without unacceptable off-target movement.	11	6	9	15	3	4	4
AC.	Determine if efficacy on hard-to-control weeds (e.g., red maple) can be increased by altering application parameters.	21	8	8	28	31	16	15
AD.	Determine if helicopter applications necessarily result in less off-target spray than fixed wing aircraft	31	28	47	40	25	36	42
AE.	Determine if helicopter applications result in better canopy penetration.	13	22	38	53	44	40	32
AF.	Determine if large or small drops are more efficacious where canopy penetration is important (i.e., multi-story canopy).	15	19	16	49	35	20	23

		CU[a]	CA[a]	CR[a]	CG[a]	UU[a]	UR[a]	CO[a]
AG.	Develop an operational remote sensing/aerial photography method for assessing aerial herbicide spray coverage shortly after application.	16	30	30	31	18	49	27
AH.[c]	Determine the effect on non-target species (plant and animal) of deposit rates from maximum label rate to the no-effect rate. Determine how long the effects last.	20	15	12	7	10	22	9
AI.	Determine appropriate, scientifically-based buffer zone widths required to prevent significant environmental impact in sensitive areas.	3	14	5	1	1	3	1
AJ.	Determine how to develop public support for aerial application of herbicides in forestry.	1	1	6	54	5	5	13
AK.	Determine the effect of adjuvants on herbicide tank mixes (possibility of phase separation, precipitation, etc.).	49	38	42	18	23	24	35
AL.	Determine the homogeneity of herbicide spray mixes (How much initial mixing is necessary? Does separation or precipitation occur? Is there a simple way to measure homogeneity in the field?)	39	33	34	46	52	53	46

		CU[a]	CA[a]	CR[a]	CG[a]	UU[a]	UR[a]	CO[a]
AM[c]	Determine the dose-response curve for environmental impact vs herbicide deposit.	14	9	7	19	28	18	8
AN.	Design a herbicide application system for reducing conifer overstocking.	57	27	48	57	58	54	53
AO.	Design ground sprayer which is less prone to tip over.	58	57	39	51	15	35	56
AP.	Design ground sprayer for which swath width varies less as machine tilts.	54	54	26	50	38	38	54
AQ.	Compare efficacy of different ground sprayers (e.g., Boomjet, air blast, Radiarc).	43	47	11	23	47	42	34
AR.	For the various ground sprayers, determine the best orifices for optimal application.	41	45	20	24	51	31	39
AS.	Design ground sprayer which can operate on currently unoperable terrain (e.g., sites currently operable only in winter or sites with very uneven terrain).	38	53	23	30	9	26	41

		CU[a]	CA[a]	CR[a]	CG[a]	UU[a]	UR[a]	CO[a]
AT.	Develop a guidance or marking system for ground sprayers to ensure that successive swaths are correctly spaced.	19	48	15	39	32	47	37
AU.	Develop a metering device for backpack sprayers when used for making spot applications of simazine.	44	49	41	10	33	56	43
AV.	Develop a flow control which is regulated by sprayer ground speed.	40	43	55	27	40	55	45
AW.	Develop a high clearance ground sprayer., i.e., one capable of straddling a row(s) of trees.	45	52	52	36	20	58	50
AX.	Design a boomless nozzle with a more uniform distribution pattern for ground sprayers.	46	42	53	33	39	39	48
AY.	Develop a good speed control system for ground sprayers.	28	46	54	35	29	44	44
AZ.	Develop equipment which can monitor application rate and spray mix remaining in tank.	42	50	58	43	36	48	52
BA.	Develop mixing and loading equipment which reduce worker exposure to herbicide.	23	37	27	6	30	34	20

		CU[a]	CA[a]	CR[a]	CG[a]	UU[a]	UR[a]	CO[a]
BB.	Develop ground application systems which can operate in higher wind conditions.	34	51	40	56	41	41	51
BC.	Develop self-leveling systems for ground sprayers.	52	55	46	41	49	57	55
BD.	Develop ground sprayers with wider spray swaths.	48	56	49	59	59	46	57
BE.	Determine the optimum tank size for ground sprayers.	59	59	56	58	57	59	59
BF.	Develop safety standards for the construction of ground sprayers.	33	41	59	42	37	45	49
BG.	Develop ground sprayers less subject to spillage following an upset.	17	44	50	26	11	51	33

[a] CU - Canadian users; CA - Canadian aerial applicators; CR - Canadian researchers; CG - Canadian regulators; UU - U.S. users; UR - U.S. researchers; CO - combined (Priorities were calculated for each of four groups [Canadian + U.S. forestry users, Canadian + U.S. researchers, Canadian aerial applicators, Canadian regulators]; these priorities were then averaged thereby giving each group equal weight in setting the priorities in the table).

[b] As these two problems are essentially the same in terms of the research required, they have been combined in the summary rankings.

	CU[a]	CA[a]	CR[a]	CG[a]	UU[a]	UR[a]	CO[a]

[c] As these two problems are essentially the same in terms of the research required, they have been combined in the summary rankings.

Silvicultural herbicides in Canada: registration status and research trends

by Robert A. Campbell[1]

Abstract

At present, there are five herbicides (2,4-D, glyphosate, hexazinone, simazine, and triclopyr) available to forest managers in Canada. It is unlikely that any new active ingredients will be registered for forestry in the foreseeable future. The only additions likely are extensions of existing labels (e.g., aerial application of Pronone® and Release®) and registration of new formulations (e.g., Velpar® ULW). Research in the short term future will concentrate on improving efficacy, efficiency and versatility, and reducing environmental impact of currently registered products. Some of the current work is described.

Key words: silviculture, herbicide, 2,4-D, glyphosate, hexazinone, simazine, triclopyr, research trends, application technology, cost-benefit, vegetation management model, environmental impact

Résumé

Actuellement, cinq phytocides (2,4-D, glyphosate, hexazinone, simazine, et triclopyr) demeurent à la disposition des gestionnaires forestiers au Canada. Il est peut probable que d'autres ingrédients actifs soient homologués en foresterie dans un proche avenir. Les seuls ajouts seront probablement constitués de la prolongation d'étiquettes existantes (p.e., l'utilisation en pulvérisation aérienne du (Pronone® et Release®) et l'homologation de nouvelles formulations (p.e., Velpar® ULW). La recherche dans un avenir à court terme se concentrera sur l'amélioration de l'efficacité, de l'efficience et de la versatilité, et sur la réduction des impact environnementaux des produits actuellement homologués. Une description de quelques-uns des travaux en cours est présentée.

Mots clés: sylviculture, phytocide, 2,4-D, glyphosate, hexazinone, simazine, triclopyr, tendances en recherche, technologie d'application, coût-bénéfice, modèle de gestion de la végétation, impact environnemental

Introduction

At the 1989 CIF Annual Meeting, I discussed three topics relating to forestry herbicide use in Canada: (i) use statistics (ii) regulatory status, and (iii) technology gaps as perceived by forest managers (Campbell 1990). This paper will cover two topics: (i) an update on registration/development status of significant forestry herbicides, and (ii) an outline of herbicide research going on in Canada at present.

Registration/Development Status (as of July 1991)

2,4-D

There has been no recent change in regulatory status (Campbell 1990). There was however, another major review of the hazard of 2,4-D to human health. The report of a workshop sponsored by the Harvard School of Public Health states, "In assessing all of the evidence on 2,4-D, workshop participants were not convinced that a cause-effect relationship between exposure to 2,4-D and human cancer exists" (Graham 1990).

Glyphosate

There was no change in status of either the registered forestry glyphosate product, Vision®, or in the development of the glyphosate-TMS product, Touchdown® (Campbell 1990).

A new glyphosate product called E-Z-JECT® has been registered. The glyphosate is formulated as a paste in small capsules, which can be injected into single undesirable woody stems using a special lance. Although the product was registered in 1990, the lance was not commercially available until early in 1991. Some efficacy data for this system can be found in Bergerud (1988).

[1]Research Scientist, Forest Pest Management Institute, Forestry Canada, Sault Ste. Marie, Ontario.

Hexazinone

Contrary to expectations (Campbell 1990), an aerial registration for Velpar® L was not obtained in time for the 1990 field season. The aerial use pattern was approved in December of 1990 but the certificate of registration (which is required before use) was not issued until June 1991. The approved aerial use is essentially the same as the ground broadcast use that has been registered since 1984. Velpar® L may be applied aerially for site preparation prior to planting. Black spruce, white spruce, and bare root jack pine stock can be planted immediately on medium and fine textured soils where the organic layer has not been removed following an application of 2.16 kg ai/ha. If rates greater than 2.16 kg ai/ha are used, or if the organic layer has been removed or severely disturbed, or if container jack pine stock is to be planted, planting should be delayed until the year following treatment. Species controlled by broadcast applications include: brome grass, bluejoint, goldenrod and raspberry. Velpar® L may not be used on coarse-textured soils. The new label specifies buffer zones around bodies of water (50 metres for ground application and 100 metres for aerial application).

Registration of Velpar® ULW (ground and aerial) and aerial registration of Pronone® were contingent upon an aerial Velpar® L registration, so it is hoped that these registrations will be granted soon.

Simazine

There has been no change in the status of simazine (Campbell 1990).

Triclopyr

Although the registrant hoped to receive registration for forestry in 1990 (Campbell 1990), a certificate of registration for ground application of Release® herbicide (triclopyr

ester) was not issued until July 1991. The approved use includes conifer release and site preparation. Application may be broadcast, single stem foliar, basal bark or cut stump. Target species include: alder, ash, birch, cherry, maple, oak, poplar, raspberry, salal, willow and many broadleaved herbaceous weeds. For broadcast site preparation, conifer planting should be delayed until the following year. The only conifers specifically listed for broadcast release are white spruce, black spruce and jack pine. There is no proscription against using the product to release other conifer species but the registrant would not be liable for crop damage.

The registrant hopes to get an aerial registration soon[3].

Sulfometuron methyl

The manufacturer still has no intention of pursuing registration in Canada.

Metsulfuron methyl, imazapyr and fluroxypyr

Three different companies are involved but the message is the same. They are still evaluating market and development costs before deciding whether to proceed with further forestry development work in Canada.

Research Trends

Rather than review all forestry herbicide research in Canada, I will discuss briefly current research trends, the reasons for these trends, and provide some examples.

Prior to the mid 1970's, there was little forestry herbicide or vegetation management research in Canada. Then, the only herbicides available to foresters were 2,4-D, 2,4,5-T and simazine. In the mid 1970's, three new active ingredients that showed promise for forestry were identified, *viz.*, glyphosate, hexazinone and triclopyr. These herbicides had the potential to control species that were thwarting forest renewal on the more productive sites and could not be controlled by existing herbicides. As a result, there was a major increase in forest herbicide research. There were still relatively few researchers working in this field, so most of the initial effort was directed to generating efficacy and tolerance data.

We now know that 2,4-D, glyphosate, hexazinone, simazine and triclopyr control competing vegetation and we know that crop trees have considerable tolerance. For this reason, little basic efficacy and crop tolerance research is being carried out at present. Furthermore, there will not likely be much in future. The long delays in obtaining forestry registrations, provincial restrictions and the constant controversy about forestry use of herbicides will discourage manufacturers from developing other forestry herbicides. This is clearly one reason for the lack of enthusiasm for development of metsulfuron methyl, imazapyr and fluroxypyr.

Although we have basic efficacy and tolerance data for the registered herbicides, there are several knowledge gaps:

1. We have not proven to the satisfaction of everyone concerned (foresters, regulators and the public) that herbicides do not cause significant negative environmental impact or adversely affect human health.
2. We have not demonstrated quantitative long-term crop benefit.
3. We know that we are not using herbicides as effectively as we could be.

Most current research is designed to address one or more of these areas of concern.

Environmental Impact/Human Health

This knowledge gap is the most important because concerns about environmental impact and human health are the most common reasons for forest herbicide use to be restricted or prohibited. Unfortunately, good science is often not enough to allay these concerns. In all seriousness, I think we need to get some social scientists working on the problem of gaining public acceptance for a tool which we believe is essential and does not pose a significant health or environmental hazard.

Environmental Fate

The first question to be asked when investigating environmental impact is, "What happens to the herbicide after it is sprayed?" (How much gets into the various environmental components? Does it move within the soil profile? How fast does it dissipate? What are the degradation products?). A lot of environmental fate work has been done on Canadian forest sites. The most active groups have been: Forest Pest Management Institute, Northern Forestry Centre, Québec Ministrère de l'Énergie et des Ressources, University of Guelph and University of Toronto (Table 1). In general, environmental fate studies, in combination with toxicity studies, have indicated that direct toxicity to fish and wildlife is unlikely under normal use conditions.

Habitat Effects

Because herbicides affect vegetation, they can affect fish and wildlife habitat. Thus, most of the research on the impact of herbicides on fish and wildlife is directed toward effects on habitat. Some examples of recent Canadian research are listed in Table 2.

Buffer Zones

In most jurisdictions, local regulatory agencies require that buffer zones be established around areas of concern (water bodies, human habitation, apiaries, etc.) during aerial spraying programs. The width of the buffer required for protection of the same resource varies dramatically from one jurisdiction to the next (Trial 1987). This is partly because there is little scientific basis for defining buffer width (Trial 1987), and what there is has frequently been weak. The first question that needs answering is, "How much herbicide drifts, and what are the effects of meteorological conditions and the delivery system?" This is not a simple question — a lot of variables must be considered and each variable has a wide range of intensities or levels. Consequently, the problem is being approached from two directions. First, drift studies are used to measure herbicide that is airborne and/or deposited downwind using different delivery systems and under different atmospheric conditions. This work is being done at the Forest Pest Management Institute (Payne *et al.* 1990) and at the Research and Productivity Council in Fredericton, NB (Riley *et al.* 1991). Data from drift studies, together with data on droplet spectra produced by different atomizers (Picot *et al.* 1989), are used in models designed to extrapolate results to other scenarios (different wind speed,

[3]It seems to be futile to try to estimate when a registration will be granted. In 1983, I stated that triclopyr was not currently registered but might be by 1984 (Campbell 1984).

Table 1. Selected environmental fate studies of herbicides on forest sites in Canada

	2,4-D	Glyphosate	Hexazinone	Triclopyr	Metsulfuron
Water	Solomon *et al.* 1988	Feng *et al.* 1990 Legris and Couture 1990	Feng and Feng 1988 Legris and Couture 1987 Solomon *et al.* 1988	Solomon *et al.* 1988 Thompson *et al.* 1991	FPMI[1] in progress
Soil	Thompson *et al.* 1984	Feng and Thompson 1990 Roy *et al.* 1989a Legris and Couture 1990	Feng 1987 Feng and Feng 1988 Legris and Couture 1987 Roy *et al.* 1989	Stephenson *et al.* 1990	FPMI[1] in progress
Sediment	Solomon *et al.* 1988	Feng *et al.* 1990 Legris and Couture 1990	Legris and Couture 1987 Solomon *et al.* 1988	Solomon *et al.* 1988 Thompson *et al.* 1991	FPMI[1] in progress
Litter		Feng and Thompson 1990			
Foliage		Feng and Thompson 1990 Legris and Couture 1990			
Berries	Frank *et al.* 1983	Legris and Couture 1990 Roy *et al.* 1989c			

[1]Forestry Canada, Forest Pest Management Institute.

Table 2. Selected habitat studies of herbicides on forest sites in Canada

	Glyphosate	Hexazinone	Triclopyr	Metsulfuron
Aquatic invertebrates	Kreutzweiser *et al.* 1989 Scrivener and Carruthers 1989	FPMI[1] in progress	FPMI[1] in progress	
Algae	Holtby and Baillie 1989a	FPMI[1] in progress		FPMI[1] in progress
Zooplankton		FPMI[1] in progress		FPMI[1] in progress
Soil fauna and microflora	Preston and Trofymow 1989			
Salmon habitat	Holtby and Baillie 1989b			
Moose habitat	Connor and McMillan 1990			
Small mammal habitat		Brace *et al.* 1988		

[1]Forestry Canada, Forest Pest Management Institute.

temperature, relative humidity, atmospheric stability, spray height, delivery system, formulation, etc). Further drift studies are then done to improve model fit. There is no perfect model, but two major ones are FSCBG, developed by the USDA Forest Service and PKBW, which was developed at the University of New Brunswick[4]. Because neither model is suitable for in-the-field decision making, Monsanto is attempting to have a new model developed which could be used to make go/no-go decisions in the field.

Knowing how much drift is going to occur in a given situation is only the first step in setting a rational buffer zone. The next question is, "How much deposit and/or impact is acceptable in the resource to be protected?" Specifying no deposit is unrealistic because the downwind distance to a no-deposit level increases as the sensitivity of detection increases. Since plants are usually the most sensitive organisms to herbicides, one approach is to utilize deposit levels which cause no effect on plants. This has been done for hexazinone (Campbell *et al.* 1986) and glyphosate (Payne, pers. commun.). It is likely that one of the requirements for registration in the future will be no-effect levels for a wide variety of non-target plants.

[4]Mickle (1987) compared the performance of these two models for insecticide drift.

Worker Exposure

Requirements for human safety associated with pesticide use have led to more research on human exposure. The study of Frank *et al.* (1985) on 2,4-D exposure was completed because workers wanted proof that they would not be harmed by working with herbicides. Exposure studies have also been done for glyphosate (Centre de Toxicologie du Québec, 1988) and hexazinone (Bertrand and Dugal 1988). Worker exposure studies are now required for new registrations. In 1990, DowElanco carried out such a study to support their submission for an aerial registration of Release® herbicide (triclopyr). Such worker exposure studies are feasible for major forestry herbicides, but when it comes to forest nursery herbicides there is a problem. No chemical company is going to spend $100,000 or more on a worker exposure study to support a herbicide that will be used on less than 50 ha per

crop tree performance[9], so research is needed to find measures of vegetation that better represent competitive pressure (Wagner *et al.* 1989).

One way of approaching the poor correlation problem is by determining the nature of competition (Does competing vegetation compete by limiting crop tree access to light, moisture or nutrients? Is allelopathy involved?). Work of this type is going on at the Newfoundland Forestry Centre, the Forest Pest Management Institute and the University of British Columbia. As an example, the strong competitive pressure exerted by *Kalmia* on black spruce does not seem to be related to light or moisture. If it is allelopathic, use of a herbicide to kill the *Kalmia* may not help the crop (B. Titus, pers. commun.).

Vegetation Management Models

In addition to the numerous factors that can affect competition indices, another problem with them is that they are static. A competition index can indicate whether the current level of competition is having a negative effect on the crop trees but it can not forecast future effects (Wagner *et al.* 1989). A logical extension of the idea of competition indices is the development of models that would predict competition and thus facilitate proactive rather than reactive vegetation management. In fact, it has been suggested that competition indices may have a fairly limited utility. Caza and Kimmins (1990) state, ''It is suggested that an approach employing dynamic simulation models responsive to changing conditions over time and space may yield greater potential for the development of management tools for the assessment and prediction of vegetation problems.'' Descriptions of a number of the growth models currently under development (ZELIG, CLUMP, FORCYTE, FORECAST, df et al.) can be found in Hamilton (1990). In addition to growth models, models are also being developed to assist in selection of the best vegetation management alternative once the need has been identified. I don't believe that any of the latter type of model are being developed in Canada, but there is one for the Pacific Northwest called VegPro (Wagner 1990) and one for southern pines called ChESS (S.M. Zedaker, pers. commun.).

Rate Refinement

This needs to be done for local conditions — optimizing rates, timing, etc. work has been done in Nova Scotia — checking lower than recommended rates (Chase *et al.* 1990) and seasonal variation in conifer tolerance (N.S. Dept. Lands and Forests 1989). A lot of this work is done by operational people. Although it is a potential source of much useful information, there are two reasons why it represents only potential. First, many trials are trying one treatment or rate one year and another the next year (i.e., there are no side by side comparisons). Second, although many of these trials result in important information, it does not get reported. The Expert Committee on Weeds Annual Research Report provides a good vehicle for communicating this type of trial and should be used more frequently. Reports are limited to one page so they are not onerous to prepare.

[9]The lack of appropriate assessment methods is one of the reasons why long-term benefit data is so variable. Such data are seldom tied to a quantitative measure of competitive pressure at the time of treatment.

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References

Bergerud, W.A. 1988. Dose-response models for stand thinning with the ''Ezject'' herbicide injection system. B.C. Min. For., Res. Br., Victoria, BC. Res. Note. No. 102. 28 p.

Bertrand, N. and J. Dugal. 1988. Concentrations d'hexazinone dans l'air et exposition des travailleurs lors d'une application terrestre, en 1988. Gouvernement du Québec, Ministère de l'Énergie et des Ressources, Direction de la conservation. Publ. 3326.

Brace, L.G., S. Sidhu, and D. Boylen. 1988. Vegetation management research project, Grande Prairie, AB: progress report. For. Can., North. For. Cent., Edmonton, AB.

Campbell, R.A. 1984. The value of herbicides in forest management. Can. For. Indust. 104 (31): 41-44.

Campbell, R.A. 1990. Herbicide use for forest management in Canada: where we are and where we are going. For. Chron. 66 (4): 355-360.

Campbell, R.A., C.A. Hope, and S.A. Nicholson. 1986. An aerial velpar drift study. Pest Control Sect., Min. Nat. Res., Maple, ON.

Caza, C.L. and J.P. Kimmins. 1990. Problems with the development and application of competition indices in complex, multispecies communities. *In* Vegetation Management: an Integrated Approach. Proceedings of the Fourth Annual Vegetation Management Workshop, 14-16 November 1989, Vancouver, BC. *Compiled by* E. Hamilton. Res. Br., B.C. Min. For., Victoria, BC. FRDA Rep. 109. pp. 30-32.

Centre de Toxicologie du Québec. 1988. Étude de l'exposition professionelle des travailleurs forestiers exposés au glyphosate. Le Centre de l'Université Laval, Sainte-Foy, PQ. 27 p.

Chase, B., T. McGrath, R. McNally, and P. Romkey. 1990. Controlling raspberry and red maple in Nova Scotia with lower than recommended rates of glyphosate. Proc. Northeast. Weed Sci. Soc. 44: 61-66.

Connor, J.F. and L.M. McMillan. 1990. Winter utilization by moose of glyphosate-treated cutovers. Ont. Min. Nat. Res., NW Ont. For. Tech. Dev. Unit, Thunder Bay, ON. Tech. Rep. #56.

Deloitte & Touche Management Consultants. 1991. Economic benefit assessment of triclopyr in forest management. Prepared for the Forest Pest Management Caucus. Deloitte & Touche Management Consultants, Guelph, ON. 111 p.

Desrochers, L. and J. Dunnigan. 1991. Mobile ground sprayers for ground application of herbicides. Forest Engineering Research Institute of Canada, Pointe Claire, PQ. 42 p. (draft). (Ce rapport sera disponsible en français aussi).

Edwards, M.B. and J.H. Miller. 1991. A comparison of site preparation herbicides — 5 yr pine growth. Presentation at the 44th Ann. Meet. South. Weed Sci. Soc., 14-16 January 1991, San Antonio, TX.

Feng, J.C. 1987. Persistence, mobility and degradation of hexazinone in forest silt loam soils. J. Environ. Sci. Health B22: 221-233.

Feng, J. and C. Feng. 1988. Determination of hexazinone residues and their fate in a New Brunswick forest. Forest Pest Manage. Inst., Can. For. Serv., Sault Ste. Marie, ON. Inf. Rep. FPM-X-81.

Feng, J.C., D.G. Thompson, and P.E. Reynolds. 1990. Fate of glyphosate in a Canadian forest watershed. 1. Aquatic residues and off-target deposit assessment. J. Agric. Food Chem. 38: 1110-1118.

Frank, R., R.A. Campbell, and G.J. Sirons. 1985. Forestry workers involved in aerial application of 2,4-D: Exposure and urinary excretion. Arch. Environ. Contam. Toxicol. 14: 427-435.

Frank, R., G.J. Sirons, R.A. Campbell, and D. Mewett. 1983. Residues of 2,4-D, dichlorprop and picloram in wild berries from treated rights-of-way and conifer release sites in Ontario, 1979-1981. Can. J. Plant Sci. 63: 195-209.

Galloway, R. 1988. Report on cleaning by aerial and ground herbicide application for conifer release. *In* Statement of evidence panel XII, maintenance: tending. Class Environmental Assessment for Timber Management on Crown Lands in Ontario. Ont. Min. Nat. Res., Toronto. pp. 147-193.

Graham, J.D., ed. 1990. The weight of the evidence on the human carcinogenicity of 2,4-D. Program on Risk Analysis and Environmental Health, Harvard School of Public Health, Boston, MA.

Hamilton, E. comp. 1990. Vegetation Management: an Integrated Approach. Proceedings of the Fourth Annual Vegetation Management Workshop, 14-16 November 1989, Vancouver, BC. Res. Br., B.C. Min. For., Victoria, BC. FRDA Rep. 109.

Holtby, L.B. and S.J. Baillie. 1989a. Effects of the herbicide Roundup (glyphosate) on periphyton in Carnation Creek, British Columbia. *In* Proceedings of the Carnation Creek Herbicide Workshop, 7-10 December 1987, Nanaimo, BC. *Edited by* P.E. Reynolds. Min. For., Victoria, BC. FRDA Rep. 063. pp. 224-231.

Holtby, L.B. and S.J. Baillie. 1989b. Effects of the herbicide Roundup (glyphosate) on coho salmon fingerlings in an oversprayed tributary of Carnation Creek, British Columbia. *In* Proceedings of the Carnation Creek Herbicide Workshop, 7-10 December 1987, Nanaimo, BC. *Edited by* P.E. Reynolds. Min. For., Victoria, BC. FRDA Rep. 063. pp. 273-285.

Howard, C.A. and W.P.L. Osborn. 1989. Trial of the air blast sprayer as a herbicide applicator for site preparation and conifer release. For. Health Protect. Sect., Min. Nat. Res., Sault Ste. Marie, ON.

Kreutzweiser, D.P., P.D. Kingsbury, and J. Feng. 1989. Drift response of stream invertebrates to aerial application of glyphosate. Bull. Environm. Contam. Toxicol. 42: 331-338.

Lavy, T.L., J.D. Mattice, J.H. Massey, and B.W. Skulman. 1990. Pesticide exposure assessment of nursery workers. USDA For. Serv., Washington, DC.

Legris, J. and G. Couture. 1987. Étude préliminaire des résidus d'hexazinone dans l'environment, suite à des travaux de préparation de terrain en milieu forestier, 1986. Gouvernement du Québec, ministère de l'Énergie et des Ressources, Service des études environnementales. Publ. No. 3317.

Legris, J. and G. Couture. 1990. Résidus de glyphosate dans un écosystème forestier suite à des pulvérisations aériennes au Québec en 1987. Gouvernement du Québec, ministère de l'Énergie et des Ressources, Services des études environnementales. Publ. No. ER90-3085.

McDonald, P.M. and G.O. Fiddler. 1989. Competing vegetation in ponderosa pine plantations: ecology and control. USDA For. Serv., Pacific SW For. Range Expt. Stn., Berkeley, CA. Gen. Tech. rep. PSW-113.

Mickle, R.E. 1987. A review of models for ULV spraying scenarios. *In* Proceedings Symposium on the Aerial Applications of Pesticides in Forestry, 20-22 October 1987, Ottawa. *Edited by* G.W. Green. Assoc. Comm. Agr. For. Aviat., Nat. Res. Coun. Can., Ottawa, ON. NRC No. 29197. pp. 179-188.

Nova Scotia Dept. Lands and Forests, Forest Research Section. 1989. Conifer susceptibility to glyphosate in Nova Scotia. Truro, NS. For. Res. Rep. No. 10.

Payne, N.J., J.C. Feng, and P.E. Reynolds. 1990. Off-target deposits and buffer zones required around water for aerial glyphosate applications. Pestic. Sci. 30: 183-198.

Picot, J.J.C., M.W. van Vliet, and N.J. Payne. 1989. Droplet size characteristics for insecticide and herbicide spray atomizers. Can. J. Chem. Eng. 67: 752-761.

Prasad, R. and B.L. Cadogan. 1987. Influence of small droplets on herbicide toxicity. *In* Proceedings Symposium on the Aerial Application of Pesticides in Forestry, 20-22 October 1987, Ottawa. *Edited by* G.W. Green. Assoc. Comm. AGr. For. Aviat., Nat. Res. Coun. Can., Ottawa, ON. NRC No. 29197. pp. 309-313.

Preston, C.M. and J.A. Trofymow. 1989. Effects of glyphosate (Roundup) on biological activity of two forest soils. *In* Proceedings of the Carnation Creek Herbicide Workshop, 7-10 December 1987, Nanaimo, BC. *Edited by* P.E. Reynolds. Min. For., Victoria, BC. FRDA Rep. 063. pp. 122-140.

Reynolds, P.E., D.G. Pitt, and M.J. Roden. 1988. Weed efficacy and crop tolerance after site preparation with liquid and granular hexazinone formulations. Proc. Northeast. Weed Sci. Soc. 42 (Suppl.): 74-78.

Riley, C.M., C.J. Wiesner, and W.A. Sexsmith. 1991. Estimating off-target spray deposition on the ground following the aerial application of glyphosate for conifer release in New Brunswick. J. Environ. Sci. Health 826: 185-208.

Roberts, J.R., K.M. Lloyd, M. Stemeroff, G.R. Stephenson, R.F. Sutton, C.R. Ellis, L.V. Edgington, and B. Payandeh. 1985. Evaluation of the biological and economic benefits of pesticide use. Monograph V. *In* Strengths and limitations of benefit-cost analyses applied to the assessment of industrial organic chemicals including pesticides. Assoc. Comm. Scient. Criteria Environm. Qual., Nat. Res. Coun. Can., Ottawa, ON. NRCC No. 23988.

Romancier, R.M. 1965. 2,4-D, 2,4,5-T, and related chemicals for woody plant control in the southeastern United States. Georgia For. Res. Coun., Macon, GA. Rep. Num. 16.

Roy, D.N., S.K. Konar, S. Banerjee, D.A. Charles, D.G. Thompson, and R. Prasad. 1989a. Persistence, movement, and degradation of glyphosate in selected Canadian boreal forest soils. J. Agric. Food Chem. 37: 437-440.

Roy, D.N., S.K. Konar, D.A. Charles, J.C. Feng, R. Prasad, and R.A. Campbell. 1989b. Determination of persistence, movement, and degradation of hexazinone in selected Canadian boreal forest soils. J. Agric. Food Chem. 37: 443-447.

Roy, D.N., S.K. Konar, S. Banerjee, D.A. Charles, D.G. Thompson, and R. Prasad. 1989c. Uptake and persistence of the herbicide glyphosate (Vision) in fruit of wild blueberry and red raspberry. Can. J. For. Res. 19: 842-847.

Salonius, P.O., K.P. Beaton, and T.S. Murray. 1991. How to estimate future competition stress to better spend herbicide dollars. For. Can. - Maritimes Reg., Fredericton, NB. Tech. Note No. 251. 4 p.

Scrivener, J.C. and S. Carruthers. 1989. Changes in invertebrate populations of the main stream and back channels of Carnation Creek, British Columbia following spraying with the herbicide Roundup (glyphosate). *In* Proceedings of the Carnation Creek Herbicide Workshop, 7-10 December 1987, Nanaimo, BC. *Edited by* P.E. Reynolds. Min. For., Victoria, BC. FRDA Rep. 063. pp.263-272.

Solomon, K.R., C.S. Bowhey, K. Liber, and G.R. Stephenson. 1988. Persistence of hexazinone (VELPAR), triclopyr (GARLON) and 2,4-D in a northern Ontario aquatic environment. J. Agric. Food Chem. 36: 1314-1318.

Smith, C.R. Silvicultural equipment reference catalogue for northern Ontario. For. Resour. Br., Ont. Min. Nat. Res., Toronto, ON.

Stephenson, G.R., K.R. Solomon, C.S. Bowhey, and K. Liber. 1990. Persistence, leachability, and lateral movement of

triclopyr (Garlon) in selected Canadian forestry soils. J. Agric. Food Chem. 38: 584-588.

Thompson, D.G., G.R. Stephenson, K.R. Solomon, and A.V. Skepasts. 1984. Persistence of (2,4-Dichlorophenoxy) acetic acid and 2-(2,4-Dichlorophenoxy)propionic acid in agricultural and forest soils of northern and southern Ontario. J. Agric. Food Chem. 32: 578-581.

Thompson, D. G., B. Staznik, D.D. Fontaine, T. Mackay, G.R. Oliver, and J. Troth. 1991. Fate of triclopyr ester (Release®) in a boreal forest stream. Environ. Toxicol. Chem. 10: 619-632.

Towill, W.D. and D.A. Archibald, 1991. A competition index methodology for northwestern Ontario. Ont. Min. Nat. Res., NW Ont. For. Tech. Dev. Unit., Thunder Bay, ON. Tech. Note TN-10. 12 p.

Trial, J., ed. 1987. Buffer zones: their application to forest insect control operations. Proceedings of The Buffer Zone Workshop Sponsored By The Eastern Spruce Budworm Council's Environmental Committee, 16-17 April 1986, Quebec City, PQ. For Pest Manage. Inst., Can. For. Serv., Sault Ste. Marie, ON.

Wagner, R.G. 1990. VegPro: a forest vegetation management prescription optimization and information system. *In* Vegetation Management: an Integrated Approach. Proceedings of the Fourth Annual Vegetation Management Workshop, 14-16 November 1989, Vancouver, BC. *Compiled by* E. Hamilton. Res. Br., B.C. Min. For., Victoria, BC. FRDA Rep. 109. p. 118.

Wagner, R.G., T.D. Petersen, D.W. Ross, and S.R. Radosevich. 1989. Competition thresholds for the survival and growth of ponderosa pine seedlings associated with woody and herbaceous vegetation. New For. 3: 151-170.

Forestry Canada Forêts Canada

MEMORANDUM NOTE DE SERVICE

TO / A: Craig A. Howard, Chairman
SERG

FROM / DE: Robert A. Campbell
Research Scientist
Herbicide Physiology
Forestry Canada - FPMI

SECURITY - CLASSIFICATION - DE SÉCURITÉ
OUR FILE — N / RÉFÉRENCE
YOUR FILE — V / RÉFÉRENCE
DATE 21 Dec 1992

SUBJECT / OBJET: User Need #8: Socio/political concerns regarding aerial application of pesticides

In the Improved Pesticide Applications Wish List survey, Canadian Users identified their number one priority as, "Determine how to develop public support for aerial application of herbicides in forestry." At the December 1, 1992 meeting of the USDA Forest Service National Steering Committee for Managing Vegetation on Forest and Range Lands, lack of support for herbicide use was identified as a major constraint to forest regeneration. I was asked to convey the Forest Service's interest in a collaborative effort with appropriate groups in Canada to determine how to gain support for the use of this essential tool.

The Ontario Vegetation Management Alternatives Program (VMAP) currently has a contract with a consultant to provide a public education plan. This will include: i) a literature survey on experiences of other jurisdictions in the asessment of public attitudes on forestry herbicide use; ii) use of focus groups to determine needs and interests of different segments of the Ontario population; and iii) based on the results of the preceding two phases, a specific public education plan. The contract is scheduled for completion by the end of March 1993.

I suggest that we take no action on this item until the reports from the VMAP project are available. These reports should provide insight into how the problem could be approached in a wider context than Ontario VMAP.

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REPORT TO NATIONAL STEERING COMMITTEE FOR APPLICATION OF PESTICIDES - VEGETATION MANAGEMENT

Dr. George Ice, NCASI[1]

I INTRODUCTION

The National Council of the Paper Industry for Air and Stream Improvement, Inc. (NCASI) is the oldest (1943) environmental research organization funded by a single industry in the United States. NCASI programs are funded by the forest products industry. Environmental questions associated with forest management have been addressed by NCASI since 1977. NCASI is not a lobbying organization but rather a research and technical information group dedicated to developing solutions to environmental questions.

The use of forest chemicals and other vegetation control techniques raises several environmental questions. First, there are concerns about toxicity and the lack of public trust about the safety of forest chemicals including herbicides. Second, implementation of new regulations and laws like the Safe Drinking Water Act, are expanding the scrutiny of chemical applications where they coincide with surface source watersheds or the zone of contribution for subsurface water supplies. Finally, emerging environmental issues such as biodiversity, protection of threatened and endangered species, and protection of species not traditionally considered (such as macroinvertebrates) are causing constraints on management options or at least new questions that need to be addressed. NCASI and its member companies are interested in understanding legitimate concerns and developing appropriate management solutions.

The industry level of concern about environmental constraints on management is demonstrated by the recommendations from the Auburn University Silvicultural Cooperative cited by Dr. Charles McMahon. Eight out of the 15 priority information needs was related to environmental issues. The report by Campbell and Howard of "Priorities for Forestry Herbicide Application Technology Research" also lists several areas such as "effective buffer widths" and "effects on non-target species" associated with environmental concerns. The NCASI forest management program has identified forest chemical use as an important issue and is addressing it through several avenues. These include projects in the NCASI Forest Water Quality Program and special efforts related to nursery and seed orchard operations.

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[1]Research Forest Hydrologist, National Council of the Paper Industry for Air and Stream Improvement, PO Box 458, Corvallis, OR 97339 (503-752-8801).

II PROGRAMS OF INTEREST

There are a number of state and federal programs which should be of interest to this committee including: state aerial herbicide monitoring programs, the TFW forest practices assessment project, new forest practice rules, a national BMP effectiveness project, state NPS program assessment, and EPA methods development for delineation of zones of contribution to groundwater sources.

A. State Monitoring of Water Quality for Aerial Applications

Several states have monitoring programs to determine the effectiveness of current programs for protecting waters near aerial forest chemical applications. In California, the North Coast Water Quality Control Board has required monitoring for all forest herbicide applications for many years. Highest concentrations are reported following heavy precipitation events and not associated with immediate drift into streams. Concentrations detected over many years are always below water quality criteria. Oregon developed a monitoring project for 50 herbicide operation units which was reported in a January 1992 report on "Forest Herbicide Application: Water Sampling Study" (1). Samples were collected using a protocol designed to determine a 24-hour mean concentration. In 83 percent of samples from nearby streams, no herbicide was detected. All samples were below recommended water quality criteria.

B. TFW Water Quality Assessment Project

In Washington, the Timber/Fish/Wildlife (TFW) agreement between agencies, environmental organizations, industry, and Indian tribes is applying adaptive management to forestry. One element of this agreement is assessment and refinement of the Washington Forest Practices Act. The Water Quality Steering Committee (WQSC) of TFW has a four part program to assess water quality impacts of aerially applied forest chemicals. The WQSC cooperated with the state of Oregon to contract for development of surface water quality criteria by Drs. Logan Norris and Frank Dost. That report "Proposed Surface Water Quality Criteria for Selected Pesticides Used for Forest Management and Management of Forest Tree Seedling Nurseries and Christmas Tree Plantations in Oregon and Washington" (2), has been accepted by the WQSC. An intensive monitoring project for seven spray units has been completed and a draft report is now being reviewed. These sites included excellent controls and high sample collection frequency. Two other projects to determine the ability of operators to detect and avoid overspray of small tributary streams during aerial spray operations and a project to evaluate application variables (ie: wind speed and direction, buffer width, height of application, boom configuration) are to be completed.

C. New Forest Practice Rules

Both Oregon and Washington have implemented new forest practice rules dealing with application of forest chemicals. In Oregon, notices of chemical application operations are now to be provided to people who may be affected up to 10 miles downstream of the application site. In Washington, the level of application detail for aerial herbicide operations is tied to the environmental considerations including toxicity rating, presence of threatened or endangered species in the spray area, potential to leach into groundwater, distance to surface water, and presence of fish hatchery or domestic water supply intake. A key for evaluation is attached as Attachment A. Applications that are classified as Class IV special require the highest operation review possible, equivalent to conducting a SEPA review.

D. National BMP Effectiveness Assessment Committee

A steering committee for "Development of a National Methodology for Evaluating the Effectiveness of Best Management Practices in Meeting Water Quality Goals or Standards" has been working under the leadership of Dr. George Dissmeyer, USDA Forest Service, Atlanta, Georgia. Of particular importance to the Pesticides Committee is work to organize literature on the effectiveness of Best Management Practices to protect water quality. This database will be on the microcomputer database Procite. The BMP Effectiveness Committee is developing an approach to assessing practice effectiveness. The concepts of this approach are summarized in a paper presented by Dr. Dissmeyer at the recent National Hydrology Workshop (3).

E. Review of NPS Programs

NCASI is coordinating reviews of state silvicultural Nonpoint Source (NPS) control programs. Four contractors are reviewing state programs in the West, Northeast, Lake States, and South. These programs include control elements dealing with forest chemicals. Drafts of these reviews have been submitted to NCASI.

F. EPA Groundwater Source Area Delineation Models

EPA has developed methodology and is sponsoring training courses for delineation of zones of contribution for identifying wellhead protection areas. Relevant documents include the WHPA 2.0 Code (A Modular Semi-Analytical Model for the Delineation of Wellhead Protection Areas) and "Delineation of Wellhead Protection Areas in Fractured Rocks" (4,5).

Additional references of relevance to the committee are attached.

III LITERATURE CITED

(1) "Forest Herbicide Application: Water Sampling Study" Forest Practices Program, Oregon Dept. of Forestry, Salem, OR (January 1992).

(2) Norris, L.A., Dost, F., "Proposed Surface Water Quality Criteria for Selected Pesticides Used for Forest Management and Management of Forest Tree Seedling Nurseries and Christmas Tree Plantations in Oregon and Washington" Washington Dept. of Natural Resources, Olympia, WA (August 20, 1992).

(3) Dissmeyer, G.E., "Aquatic Ecosystem Approach to Monitoring" Paper Presented at the National Hydrology Workshop, Phoenix, AR (April 1992).

(4) Blandford, T.N., Huyakorn, P.S., "WHPA 2.0 Code: A Modular Semi-Analytical Model for Delineation of Wellhead Protection Areas", American Institute of Hydrology, Minneapolis, MN (March 1991).

(5) Wisconsin Geological and Natural History Survey, "Delineation of Wellhead Protection Areas in Fractured Rocks", EPA 570/9-91-009 (June 1991).

Charles McMahon
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USFS Forest Pest Management
National Steering Committee - Vegetation Management
Report by C. McMahon, Southern Forest Experiment Station
Auburn, AL
December 1992, Davis, CA

1. Introduction

The December 1992 meeting of the National Steering Committee for Vegetation Management is very timely. Important new policies and issues related to multi-resource management are emerging as "Ecosystem Management" on National Forest System Lands and "Forest Stewardship" on private non-industrial lands. In both cases, there is a need for innovative vegetation management options to support these "new forestry" concepts. We especially see a need to expand research and technology to support selective ground herbicide application systems such as streamline basal sprays, directed foliar sprays, and tree injection. These target oriented, non-broadcast methods are environmentally safe, and suitable for enhancing wildlife, T&E species, and recreational habitats. They can also play a crucial role in developing strategies for unevenaged and mixed stand management.

2. Recent Activities

The following are some brief highlights of recent activities of the USFS vegetation management research project in Auburn, AL. A project summary and list of publications is also attached.

A. **The project continues to conduct research and summarize findings related to the fate and transport of forest herbicides in the South.**

1. Results continue to show that forest herbicides are environmentally safe when applied correctly at labeled rates. Approaches for communicating herbicide risks in forest ecosystems were also summarized and published.

2. A major field dissipation study on the fate of hexazinone in forest ecosystems was completed in 1992. The work was performed under FIFRA Good Laboratory Practices (GLP) regulations and has been used by the sponsor for reregistration purposes. Analytical methods for concurrent analysis of hexazinone and its metabolites in soil, water, and vegetation were developed.

3. In cooperation with Auburn University, the impacts of high rate (6.7 kg/ha) applications of hexazinone (Velpar) on benthic macroinvertebrates and fish communities were evaluated in small headwater streams in Alabama. No adverse impacts were found (using a variety of indices and USA EPA rapid bioassessment protocols).

4. Studies are underway to monitor off-site movement of herbicides (probably triclopyr) to be used in the "New Perspectives" research program on the Ouachita National Forest.

5. Findings were published reporting no herbicide residues in smoke from prescribed fires on sites treated with imazapyr, triclopyr, hexazinone, and picloram.

6. In cooperation with the University of Georgia and the Southeastern Station, work continues on the validation of hydrologic/pesticide models for forest ecosystem applications.

B. **Efforts continue to conduct research and transfer the technology for the safe and effective ground application of forest herbicides.**

1. A user-manual on ground applications, first published in 1988, was revised in April 1990 and distributed to 3,000 users. This popular manual was translated into Chinese in 1991. The USFS Southern Region/Southern Station Technology Transfer Plan for Ground Applications, first published in 1987, was revised and updated in 1991.

2. In 1991, a manual on standard methods and terms for forest herbicide research was published in cooperation with the Southern Weed Science Society and Auburn University. Standardized techniques will permit more valid comparisons of study results among vegetation management investigators and practitioners.

3. ChESS (Chemical Expert System for Silviculture), a computer based decision support system for prescribing herbicides for southern pine management, was published by VPI&SU in September 1990 in collaboration with the USFS Vegetation Management Research Project at Auburn and other cooperators.

4. "Pests and Pesticide Management in Southern Forests," a unified training manual for pesticide applicators in the South is now ready for distribution. This cooperative effort sponsored by the Southern Group of State Foresters was compiled by a committee led by Jim Miller (USFS - Auburn) with editorial assistance by USFS Region 8.

5. Annual measurements continue on the South-wide study, Competition Omission Monitoring Project) (COMP) to determine how woody and herbaceous competition affect early growth of loblolly pine. Fifth-year results published in the November 1991 Southern Journal of Applied Forestry show average volume increases of 67% for woody control, 171% for herbaceous control, and 424% for total control as compared to check plots. The effects of these competition treatments on soil nitrogen, carbon storage, and nutrient transfer are now being studied in collaboration with Auburn University. A report on plant succession on these sites has been submitted for publication in the Southern Journal of Applied Forestry.

6. Cooperative work with Tuskegee University and other historically black universities is exploring the use of goats for noxious weed control (kudzu) and other forest vegetation management/agroforestry alternatives.

7. Cooperative work continues with Chinese researchers on forest herbicide use and application technology.

C. **The project continues to collaborate with University and State extension groups in the South on workshops for training and certifying herbicide applicators.**

1. In the past five years, 18 workshops have been held in the states of LA, MI, AL, GA, FL, NC, and SC training approximately 2,200 personnel. In 1991, the project provided support for the National Advanced Pesticide Management Training Program held in Marana, AZ.

D. In conjunction with long-term studies on the silviculture of longleaf pine, **the project continues to conduct research on the impact of season of burn and frequency of prescribed fire on the composition and structure of midstory and understory vegetation in pine stands.**

E. **Auburn University was host to an International (IUFRO) Conference on Forest Vegetation Management April 27 - May 1, 1992.** This meeting was designed to provide a forum on recent advances in ecology, practice and policy of forest vegetation management. A book of abstracts was published and several full papers will be published in a special edition of the Canadian Journal of Forest Research. The USFS Vegetation Management Project in Auburn provided support in the planning and conduct of the meeting. A tour of a nearby COMP research site highlighted long-term vegetation management research in progress.

3. Issues for Committee Discussion

1. The very conservative position that the Forest Service takes regarding the use of herbicides on public lands is dominating the public imagery about forest herbicides. A more balanced message is needed which affirms that there are many different "correct" approaches to vegetation management depending on the land ownership and land/ecosystem objective. This broader and more balanced image will become more important as the Forest Service expands its role into international forestry where basic survival needs urgently call for intensive forest management practices including the safe use of forest herbicides.

2. Revised NEPA Policy & Procedures continues to place unjustified constraints and obstacles on the use of herbicides on NFS lands. It propagates the paranoia which surrounds the term "herbicide." We don't see similar language for the more toxic "insecticides" or "fungicides." We confuse our public with this explicit anti-herbicide language and are quickly closing the lid on this valuable vegetation management tool. This comes at a time when highly selective and safe ground application techniques will be needed on public lands to meet "new perspectives" goals for uneven aged-mixed stands, enhanced wildlife habitat and forest aesthetics. Furthermore, our ultra-conservative stand on herbicide use on public lands may be seen by the layman as reason to condemn the more liberal but equally safe use of herbicides on small private tree-farms or industrial tracts. The South is dominated (approx. 70 percent) by private land ownership. We especially need to educate and encourage the public to understand the plurality of "acceptable" approaches to forest land management based on different management objectives for public vs private land.

3. There is a need for better coordination of vegetation management topics among WO Research staff groups
   - FMR - Veg. Mg't in general (Ecosystem Mg't, forest stewardship, noxious weed control.)
   - FER - Impacts of veg. mg't treatments on forest ecosystems (water quality, T&E Species, aquatic & riparian habitat etc.)
   - FFASR - Prescribed Fire research
   - FPM - Herbicide Technology, use data, alternatives to chemical herbicides

4. There is a need for better support of veg. mg't projects in the WO-FPM technology program. Why was vegetation management needs not supported in FY92?

5. There is a need for more documentation about forest herbicide use patterns and rates on a state and national level. The Forest Service has good data for National Forests. Virginia has excellent data, for that state. Other programs need to be initiated/supported to help dispel the myths about forest herbicides by having a factual readily available database.

6. The S&PF needs (especially for non-industrial private landowners) for veg. mg't and herbicide technology need to be more formally recognized and addressed by Forest Service programs. Ecosystem management on NFS lands tends to overshadow the S&PF needs (especially in the past few years).

4. <u>Vegetation Management Needs</u>

1. Herbicide ground application technology developments and refinements.

2. Computer based decision support systems for integrated vegetation management prescriptions. Including technology transfer and customizing of existing systems such as ChESS.

3. Veg. Mg't prescriptions for meeting ecosystem management objectives on NFS lands.

4. Veg. Mg't prescriptions for meeting forest stewardship objectives for S&PF clients.

5. Cumulative impacts from vegetation management treatments on aquatic and riparian systems.

6. Impacts of herbicides on T&E species.

7. Vegetation management impacts on soil productivity and plant diversity.

8. Application of hydrologic models for movement of chemicals in forest ecosystems.

9. Improved methods for pesticide monitoring and analysis. (Lower cost, more rapid and reliable methods.)

10. Support for <u>long-term</u> efficacy and ecosystem impact research studies (carried through a rotation).

11. Improved coordination of the risk assessment process and incorporation of fundamental principles of risk/benefit communication in worker training programs and public announcements.

FOREST SERVICE
U S
RESEARCH

Vegetation Management

Research Project

Southern Forest Experiment Station

Auburn, Alabama

VEGETATION *MANAGEMENT*

RESEARCH

PROJECT SUMMARY

"Caring for the Land and Serving People"

Vegetation Management Research Project
SO-4105; *Charles K. McMahon, Project Leader*

Project Title
Environmental impacts and ecosystem responses to vegetation management in southern forestry

Research Teams

1. **Environmental fate and ecosystem impacts of forest herbicides.**
   Team Leader: J. Michael, contributing scientists, C. McMahon, J. Fischer, H. Gibbs

   - Watershed scale studies of forest herbicide dissipation (movement and fate in soil, water and vegetation).
   - Fate of herbicides in forest fires and worker risk assessment.
   - Herbicide monitoring technology.
     - Sampling methods development
     - Analytical methods development
   - Aquatic and riparian impacts.
   - Hydrologic model applications to forest ecosystems.
   - Technology transfer.

2. **Vegetation Management research and prescription development for southern forest ecosystems.**
   Team Leader: J. Miller, contributing scientists W. Boyer, C. McMahon

   - Herbicide prescription research and development for non-industrial private landowners and National Forest Systems (Ground Application Technology).
   - Competition-crop interactions and pine growth response. (long-term, regional studies)
   - Vegetation management impacts on soil productivity and plant diversity.
   - Alternatives to herbicides for kudzu control.
   - Influence of competition on nutrient circulation and carbon and nitrogen flux.
   - Technology transfer.

3. **Longleaf Pine Ecology and Management.**
   Team Leader: W. Boyer

   - Longleaf pine ecology and management guidebook.
   - Long-term regeneration and fire ecology studies.
   - Demonstrations of natural regeneration systems and even vs. uneven-aged management.
   - Management of Escambia Experimental Forest (EEF).
   - Technology transfer.

Research Scientists

Charles K. McMahon, Research Chemist & Project Leader
Dr. William D. Boyer, Research Forester
Dr. Jerry L. Michael, Research Ecologist
Dr. James H. Miller, Research Forester

Support Scientists

Joseph B. Fischer, Chemist
Hilliard L. Gibbs, Jr., Physical Scientist

Support Staff

Erwin Chambliss, Forestry Technician
Juanita Crawford, Project Secretary
Charles Mitchell, Physical Science Technician
Ronald Tucker, Physical Science Technician
George Ward, Forestry Technician, Located at Escambia Experimental Forest (EEF)

Temporary Staff

Evelyn Cannon, *SCSEP, Office/Lab Aid*
Heidi Fishburn, Computer Clerk
Kelly Robinson, *Computer Assistant*
William Thompson, Forestry Aid (EEF)

Specialized Resources

G. W. Andrews Forestry Sciences Lab

- Environmental Chemistry lab, mass spectrometry lab, soils lab, radioisotope lab, herbarium, sample prep and drying lab, freezer storage, greenhouse, growth chamber.
- Field equipment and samplers for environmental fate studies.
- Selected studies are conducted in compliance with EPA's Good Laboratory Practice regulations.

Escambia Experimental Forest

- This 3000 acre experimental forest in south Alabama is under a 99 year lease from the T.R. Miller Mill Company of Brewton, AL. It was established in 1947 and supports many long-term longleaf pine research studies and demonstration areas.

Cooperative Research

- All studies are conducted in cooperation with numerous partners and/or co-investigators from universities, industry, National Forest Systems, other Forest Service research units, federal and state forestry agencies and private landowners.

Vegetation Management

Research Project

Southern Forest Experiment Station

Auburn, Alabama

VEGETATION *MANAGEMENT*

RESEARCH

PUBLICATIONS

"Caring for the Land and Serving People"

Enclosed is a list of abstracts and publications by scientists and cooperators of the U.S. Forest Service Vegetation Management Research Project at Auburn, AL. The project's current mission is to determine the environmental fate and ecosystem impacts of forest herbicides, and to develop safe and effective integrated vegetation management prescriptions for multiple resource benefits in southern forestry. The project also continues to support long-term studies related to the silviculture of longleaf pine.

To obtain copies, please return the form on the reverse side of this page.

Charles K. McMahon
Project Leader
Vegetation Management Research

VEGETATION MANAGEMENT RESEARCH PROJECT
SOUTHERN FOREST EXPERIMENT STATION
U.S. FOREST SERVICE
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PUBLICATION LIST

VEGETATION MANAGEMENT RESEARCH PROJECT
U.S. FOREST SERVICE
SOUTHERN FOREST EXPERIMENT STATION
AUBURN UNIVERSITY, AL 36849

1980

1. Michael, J. L. 1980. Long-term impact of aerial application of 2,4,5-T to longleaf pine (Pinus palustris). Weed Science. 28(3): 255-275.

2. Michael, J. L. 1980. Response of saw palmetto to three herbicides during the first growing season. In: Proceedings, 33rd Annual Meeting Southern Weed Science Society; 1980 January 15-17; Hot Springs, Arkansas. [Champaign, IL]: Southern Weed Science Society. 120-123.

3. Michael, J. L. 1980. Formulation rate and season of application effects of hexazinone (Velpar) gridball on oak topkill. In: Proceedings, 33rd Annual Meeting Southern Weed Science Society; 1980 January 15-17; Hot Springs, Arkansas. [Champaign, IL]: Southern Weed Science Society. 110-113.

4. Miller, James H. 1980. Competition after windrowing or single-roller chopping for site preparation in the southern piedmont. In: Proceedings, 33rd Annual Meeting Southern Weed Science Society; 1980 January 15-17; Hot Springs, Arkansas. [Champaign, IL]: Southern Weed Science Society. 139-145.

5. Miller, James H.; Bace, A. C. Jr. 1980. Streamwater contamination after aerial application of a pelletized herbicide. Research Note SO-255. U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 4 p.

1981

6. Michael, J. L. 1981. Effect of pellet size on defoliation and estimated kill of small stems treated with hexazinone. In: Proceedings, 34th Annual Meeting Southern Weed Science Society; 1981 January 20-22; Hot Springs, Arkansas. [Champaign, IL]: Southern Weed Science Society. 192-196.

7. Gordon, R.; Miller, J. H.; Brewer, C. 1981. Site preparation treatments and nutrient loss following complete harvest using the Nicholson-Koch mobile chipper. In: Barnett, J. P. ed. Proceedings, First Biennial Southern Silvicultural Research Conference, 1981 November 6-7. Atlanta, GA. Gen. Tech. Rep. SO-34. New Orleans, LA: U.S. Department of Agriculture, Forest Service: 79-84.

8. Boyer, W. D. 1981. Site and stand factors affecting height growth curves of longleaf pine plantations. In: Barnett, J. P. ed. Proceedings, First Biennial Southern Silvicultural Research Conference, 1980 November 6-7. Atlanta, GA. Gen. Tech. Rep. SO-34. New Orleans, LA: U.S. Department of Agriculture, Forest Service: 184-187.

9. Miller, James H. 1981. A comparison of cation sampling in forest soils by tension and tension-free lysimeters. In: Barnett, J. P. ed. Proceedings, First Biennial Southern Silvicultural Research Conference, 1980 November 6-7. Atlanta, GA. Gen. Tech. Rep. SO-34. New Orleans, LA: U.S. Department of Agriculture, Forest Service: 317-322.

10. Sung, S. S.; Gjerstad, D. H.; Michael, J. L. 1981. Hexazinone persistence in two different type of soils. In: Proceedings, 34th Annual Meeting Southern Weed Science Society; 1981 January 20-22; Hot Springs, Arkansas. [Champaign, IL]: Southern Weed Science Society: 152. Abstract.

11. Boyer, W. D. 1981. Thirty years of management on a small longleaf pine forest. Southern Journal of Applied Forestry. 5(2): 73-77.

12. Golden, Michael S.; Meldahl, Ralph; Knowe, Steven A.; Boyer, William D. 1981. Predicting site index for old-field loblolly pine plantation. Southern Journal of Applied Forestry. 5(3): 109-114.

13. Wells, Martha J.M.; Clark, Randall C.; Patterson, Richard M. 1981. Correlation of reversed-phase capacity factors for barbiturates with biological activities, partition coefficients, and molecular connectivity indices. Journal of Chromatographic Science. 19: 573-582.

14. Wells, Martha J.M.; Clark, Randall C. 1981. Liquid chromatographic elution characteristics of some solutes used to measure column void volume on C_{18} bonded phases. Analytical Chemistry. 53: 1341-1345.

15. Martin, R.; Miller, J. H. 1981. Soil active herbicides for kudzu control report of a screening study. Highlights of Research 28(4). Agricultural Experiment Station, Auburn University, AL. 1 p.

1982

16. Wells, M.J.M.; Clark, C.R. 1982. CHROM. 14,268. Investigation of N-Alkylbenzamides by reversed-phase liquid chromatography. I. Isocratic elution characteristics of the C^1-C_5 N-alkylbenzamides. Journal of Chromatography. 235(1982): 31-41.

17. Wells, M.J.M.; Clark, C.R; Patterson, R.M. 1982. CHROM. 14,269. Investigation of N-Alkylbenzamides by reversed-phase liquid chromatography. II. Application of the solvophobic theory to the prediction or retention data for the C^1-C_5 N-alkylbenzamides. Journal of Chromatography. 235(1982): 43-59.

18. Wells, M.J.M.; Clark, C.R.; Patterson, R.M. 1982. CHROM. 14,270. Investigation of N-Alkylbenzamides by reversed-phase liquid chromatography. III. Correlation of chromatographic parameters with molecular connectivity indices for the C^1-C_5 N-alkylbenzamides. Journal of Chromatography. 235(1982): 61-74.

19. Miller, J.H. 1982. Hardwood control using pelleted herbicides and burning. In: Proceedings, 35th Annual Meeting Southern Weed Science Society; 1982 January 19-21; Atlanta, GA. [Champaign, IL]: Southern Weed Science Society. 210-215.

20. Miller, J.H. 1982. Kudzu control chemicals. In: Proceedings, 35th Annual Meeting Southern Weed Science Society; 1982 January 19-21; Atlanta, GA. [Champaign, IL]: Southern Weed Science Society. 241-243.

21. Sung, S.S.; Gjerstad, D.H.; Michael, J.L. 1982. Loblolly pine (Pinus taeda L.) photosynthesis inhibition by hexazinone and metabolites. In: Proceedings, 35th Annual Meeting Southern Weed Science Society; 1982 January 19-21; Atlanta, GA. [Champaign, IL]: Southern Weed Science Society. 244. Abstract.

22. Michael, J.L. 1982. Some new possibilities to control kudzu. In: Proceedings, 35th Annual Meeting Southern Weed Science Society; 1982 January 19-21; Atlanta, GA. [Champaign, IL]: Southern Weed Science Society. 237-240.

23. Wells, Martha J.M.; Clark, C. Randall. 1982. CHROM. 14,867. Investigation of N-alkylbenzamides by reversed-phase liquid chromatography. IV. The study of a homologous series of N-alkylbenzamides using the solvophobic theory and molecular connectivity. Journal of Chromatography 243(1982): 263-277.

24. Wells, M.J.M.; Clark, C. Randall. 1982. CHROM. 14,931. Investigation of N-alkylbenzamides by reversed-phase liquid chromatography. V. Characteristics of some tertiary alkylbenzamides. Journal of Chromatography 244(1982): 231-240.

25. Wells, M.J.M. 1982. The effect of silanol masking on the recovery of picloram and other solutes from a hydrocarbonaceous pre-analysis extraction column. Journal of Liquid Chromatography. 5(12): 2293-2309.

26. Carter, G.A.; Miller, J.H.; Davis, D.E.; Patterson. R.M. 1982. Effect of vegetative competition on the moisture and nutrient status of loblolly pine (Pinus taeda L.). Bul. Ecol. Soc. Amer. 63(2): 103. Abstract.

1983

27. Miller, J.H.; Newton, M. 1983. Nutrient loss from disturbed forest watersheds in Oregon's Coast Range. Agro-Ecosystems 8: 153-167.

28. Boyer, W.D. 1983. Variations in height-over-age curves for young longleaf pine plantations. Forest Science 29: 15-27.

29. Boyer, W.D. 1983. Growth of young longleaf pine as affected by biennial burns plus chemical or mechanical treatments for competition control. In: Proceedings Second Biennial Southern Silvicultural Research Conference, 1982 November 4-5; Atlanta, GA. Gen. Tech. Rep. SE-24. Asheville, NC: U.S. Department of Agriculture, Forest Service: 62-65.

30. Michael, J.L. 1983. Pine tolerance to some new chemicals. In: Proceedings, 36th Annual Meeting Southern Weed Science Society; 1983 January 18-20; Biloxi, MS. [Champaign, IL]: Southern Weed Science Society. 218-221.

31. Boyer, W.D.; Patterson Donald W. 1983. Longleaf pine. In: Silvicultural Systems for the Major Forest Types of the United States. Russell M. Burns Technical Compiler. U.S. Department of Agriculture, Forest Service, Agricultural Handbook No. 445. 153-156.

32. Michael, J.L.; Boyer, W.D. 1983. Forestry herbicides. Forest Farmer 42(8): 6-7.

33. Miller, J.H. 1983. A regression-adjusted approach can estimate competing biomass. In: Proceedings Second Biennial Southern Silvicultural Research Conference, 1982 November 4-5; Atlanta, GA. Gen. Tech. Rep. SE-24. Asheville, NC: U.S. Department of Agriculture, Forest Service: 344-351.

34. Banker, R.E.; Miller, J.H.; Davis, D.E. 1983. First-year effects of rootraking on available nutrients in Piedmont Plateau soils. In: Proceedings Second Biennial Southern Silvicultural Research Conference, 1982 November 4-5; Atlanta, GA. Gen. Tech. Rep. SE-24. Asheville, NC: U.S. Department of Agriculture, Forest Service: 23-25.

35. Edwards, M.B.; Miller, J.H. 1983. So you want to get rid of your kudzu. Alabama Forests 26(2): 11-12.

36. Miller, J.H.; Edwards, Boyd. 1983. Kudzu: where did it come from? And how can we stop it? Southern Journal of Applied Forestry. 7: 165-169.

1984

37. Wells, M.J.M.; Clark, C.R. 1984. CHROM. 16,264. Study of the relationship between dynamic and static equilibrium methods for the measurement of hydrophobicity. Comparison of capacity factors and partition coefficients for some 5,5-disubstituted barbituric acids. Journal of Chromatography. 284(1982): 319-335.

38. Clark, C.R.; Wells, M.J.M.; Sansom, R.T.; Humerick, J.L.; Brown, W.B.; Commander, B.J. 1984. Effects of intramolecular hydrogen bonding on solute retention in reversed-phase liquid chromatography. Elution characteristics of some isomeric benzamides. Journal of Chromatographic Science. 22: 75-79.

39. Wells, M.J.M.; Michael, J.L.; Neary, D.G. 1984. Determination of picloram in soil and water by reversed-phase liquid chromatography. Archives of Environmental Contamination and Toxicology. 13: 231-235.

40. Michael, J.L. 1984. Impacts of rate of hexazinone application on survival and growth of the loblolly pine. In: Proceedings, 37th Annual Meeting Southern Weed Science Society; 1984 January 17-19; Hot Springs, AR. [Champaign, IL]: Southern Weed Science Society. 210-213.

41. Carter, G.A.; Miller, J.H.; Davis, D.E.; Patterson, R.M. 1984. Effect of vegetative competition on the moisture and nutrient status of loblolly pine. Canadian Journal of Forest Research. 14(1): 1-9.

42. Miller, J.H. 1984. Soil-active herbicides for single-stem and stand hardwood control. In: Proceedings, 37th Annual Meeting Southern Weed Science Society; 1984 January 17-19; Hot Springs, AR. [Champaign, IL]: Southern Weed Science Society. 173-181.

43. Clark, R.C.; Wells, M.J.M.; Sansom, R.T.; Norris, G.N.; Dockens, R.C.; Ravis, W.R. 1984. Anticonvulsant activity of some 4-aminobenzamides. Journal of Medicinal Chemistry. 27(6): 779-782.

44. Pitcher, J.A. 1984. Geographic variation patterns in seed and nursery characteristics of black cherry. U.S. Department of Agriculture, Forest Service; Southern Forest Experiment Station, Research Paper SO-208.

45. Neary, D.G.; Michael, J.L.; Lenz, G.W.; Mroz, G.D.; Jurgensen, M.F. 1984. Fate of picloram and hexazinone in a cutover northern forest after treatment with herbicides for site preparation. Bul. Ecol. Soc. Amer. 65(2): 191. Abstract.

46. Miller, James H. 1984. Where herbicides fit into forest management schemes. In: Proceedings Fourth Annual Forestry Forum. 1984 March 21; Clemson, SC. Clemson University Cooperative Extension Service. 1-13.

1985

47. Michael, J.L. 1985. Growth of loblolly pine treated with hexazinone, sulfometuron methyl, and metsulfuron methyl for herbaceous weed control. Southern Journal of Applied Forestry. 9: 20-26.

48. Michael, J.L. 1985. Hardwood control by injection with two new chemicals. In: Proceedings, 38th Annual Meeting Southern Weed Science Society; 1985 January 14-16; Houston, TX. [Champaign, IL]: Southern Weed Science Society. 164-167.

49. Boyer, W.D. 1985. Timing of longleaf seedling release from over topping hardwoods: A look 30 years later. Southern Journal of Applied Forestry. 9: 114-116.

50. Boyer, W.D. 1985. First-year survival of planted longleaf pine bare-root and container stock as affected by site preparation and release. In: Proceedings Third Biennial Southern Silvicultural Research Conference, 1984 November 7-8; Atlanta, GA. Gen. Tech. Rep. SO-54. New Orleans, LA: U.S. Department of Agriculture, Forest Service: 74-78.

51. Miller, J.H. 1985. Testing herbicides for kudzu eradication on a Piedmont site. Southern Journal of Applied Forestry 9: 128-132.

52. Miller, J.H.; Edwards, M.B. 1985. Impacts of various intensities of site preparation on Piedmont soils after 2 years. In: Proceedings Third Biennial Southern Silvicultural Research Conference, 1984 November 7-8; Atlanta, GA. Gen. Tech. Rep. SO-54. New Orleans, LA: U.S. Department of Agriculture, Forest Service: 65-73.

53. Miller, J.H. 1985. Banded herbicides can be as effective as windrowing. In: Proceedings, 38th Annual Meeting Southern Weed Science Society; 1985 January 14-16; Houston, TX. [Champaign, IL]: Southern Weed Science Society. 216-225.

54. Miller, J.H.; Zhongze, Qiu; Sirois, D.L. 1985. Ground sprayer designs for forestry applications. In: Proceedings, 38th Annual Meeting Southern Weed Science Society; 1985 January 14-16; Houston, TX. [Champaign, IL]: Southern Weed Science Society. 271-282.

55. Neary, D.G.; Michael, J.L.; Wells, M.J.M. 1985. Fate of hexazinone and picloram after herbicide site preparation in a cutover northern hardwood forest. In: Mroz and Trettin, C.C., ed. Forest soils: A resource for intensive forest management: Proceedings 1984 Lake States Forest Soils Conference Miscellaneous Publication 85-1. School of Forestry and Wood Products, Michigan Technological University Press; 55-72.

56. Neary, Daniel G.; Michael, Jerry L.; Bush, Parshall B.; Taylor, John W. 1985. Effectiveness of hexazinone as a forestry herbicide. Forestry Bulletin R8-FB/P 16. Forestry Pesticides Fact Sheet Number 4. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region; April. 2 p.

57. Miller, James H. 1985. Ground Applications. In: Proceedings Herbicides in Forestry; 1985 December 12-13; Athens, GA. Athens, GA: University of Georgia, Center of Continuing Education. 35-55.

58. Michael, J.L.; Neary, D.G. 1985. Response of saw palmetto to three herbicides. In: Herbicides for Southern Forestry, compiled and edited by Plywell, Nancy A.; Neary, Daniel; Law, Beverly from Proceedings of the 17th Annual Spring Symposium: 1985 April 23-24; Gainesville, FL: School of Forest Resources and Conservation and Florida Society of American Foresters.
183-185.

59. Neary, D.G.; Michael, J.L. 1985. Herbicides in Florida's flatwoods-efficacy and opportunity. In: Herbicides for Southern Forestry, compiled and edited by Plywell, Nancy A.; Neary, Daniel; Law, Beverly from Proceedings of the 17th Annual Spring Symposium: 1985 April 23-24; Gainesville, FL: School of Forest Resources and Conservation and Florida Society of American Foresters. 194-201.

60. Wells, Martha J.M. 1985. General procedures for the development of adsorption trapping methods used in herbicide residue analysis. In: Proceedings Second Annual International Symposium, Sample Preparation and Isolation using Bonded Silicas, 1985 January 14-15. Franklin Plaza, Philadelphia, PA. Published by Analytichem International, Inc. 24201 Frampton Ave., Harbor City, CA 90710. 63-68.

1986

61. Pitcher, John A.; Risbrudt, Christopher D. 1986. Revising the forestry incentives program for the South. Southern Journal of Applied Forestry. 10: 6-10.

62. Miller, James H. 1986. Kudzu eradication trials testing fifteen herbicides. In: Proceedings, 39th Annual Meeting Southern Weed Science Society; 1986 January 20-22; Nashville, TN. [Champaign, IL]: Southern Weed Science Society. 276-281.

63. Michael, J.L. 1986. Pine regeneration with simultaneous control of kudzu. In: Proceedings, 39th Annual Meeting Southern Weed Science Society; 1986 January 20-22; Nashville, TN. [Champaign, IL]: Southern Weed Science Society. 282-288.

64. Risbrudt, Christopher D.; Pitcher, John A. 1986. Financial returns from timber stand improvement investments. Northern Journal of Applied Forestry. 3: 52-58.

65. Birdsey, Richard A.; Pitcher, J.A. 1986. Management option for poorly stocked stands in the South Central United States. Southern Journal of Applied Forestry. 10: 73-77.

66. Neary, D.G.; Bush, P.B.; Michael, J.L. 1986. Herbicides in southern forestry-improving water quality. In: Proceedings, 39th Annual Meeting Southern Weed Science Society; 1986 January 20-22; Nashville, TN. [Champaign, IL]: Southern Weed Science Society. 335-341.

67. Wells, Martha J.M. 1986. Multistage preparation schemes for off-line extraction chromatography of herbicides in environmental samples. Proceedings, Tenth International Symposium on Column Liquid Chromatography; 1986 May 18-23; San Francisco, CA. 708. Abstract.

68. Williamson, Max; Miller, James H. 1986. Hand application methods for commonly used forestry herbicides in the South. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region. 12 p.

69. Miller, James H.; True, Ronald E. 1986. Herbicide tests for kudzu eradication. Macon, GA: Georgia Forestry Commission; Georgia Forest Research Paper 65. 11 p.

70. Nash, Ralph G.; Wells, Martha J.M.; Smith, Allan E.; VanWambeke, E. 1986. Pesticide residues in environmental samples. In: Analytical Methods for Pesticides and Plant Growth Regulators, Vol. XV. Academic Press, New York, N.Y. Chapter 9. 247-286.

71. Miller, James H.; Sirois, Donald L. 1986. Soil disturbance by skyline yarding vs. skidding in a loamy hill forest. Soil Science Society of American Journal. 50: 1579-1583.

72. Wells, Martha J.M. 1986. Off-line multistage extraction chromatography of ultraselective herbicide residue isolation. In: Sample Preparation and Isolation Using Bonded Silicas: Proceedings, Third Annual International Symposium; 1986 May 5-6; Cherry Hill, NJ. [Harbor City, CA]: Analytichem International, Inc. 117-135.

73. Neary, D.G.; Bush, P.B.; Michael, J.L. 1986. Fate of hexazinone and picloram in Southern United States Forest Watersheds. The Sixth International Congress of Pesticide Chemistry IUPAC 1986 August 10-15; Ottawa, Canada. 6B-15. Abstract.

74. Neary, D.G.; Bush, P.B.; Michael, J.L.; Taylor, J.W. 1986. Effectiveness of 2,4-D and picloram. Forestry Bulletin R-8 FB/P28, U.S. Department of Agriculture, Forest Service; Forest Pest Management Technology Update. 2 p.

1987

75. Miller, James H.; Zutter, Bruce. 1987. A region-wide study of loblolly pine seedlings growth relative to four competition levels after two growing seasons. In: Proceedings Fourth Biennial Southern Silvicultural Research Conference, 1986 November 4-6; Asheville NC. Gen. Tech. Rep. SE-42. Atlanta, GA: U.S. Department of Agriculture, Forest Service: 581-592.

76. Boyer, William D. 1987. Annual and Geographic variations in cone production by longleaf pine. In: Proceedings Fourth Biennial Southern Silvicultural Research Conference, 1986 November 4-6; Asheville NC. Gen. Tech. Rep. SE-42. Atlanta, GA: U.S. Department of Agriculture, Forest Service: 73-76.

77. Miller, James H.; Burkhardt, E.C. 1987. A trial of herbicide treatments for enrichment plantings of cherrybark oak. In: Proceedings of the Central Hardwood Forest Conference VI; 1987 February 24-26; Knoxville, TN. Knoxville, TN: University of Tennessee: 53-58.

78. Michael, J.L.; Neary, D.G. 1987. Off-site movement of picloram from a coastal plain kudzu site. In: Proceedings, 40th Annual Meeting Southern Weed Science Society; 1987 January 12-14; Orlando, FL. [Champaign, IL]: Southern Weed Science Society. 397. Abstract.

79. Neary, D.G.; Bush, Parshall B.; Michael, Jerry L. 1987. Fate of hexazinone and picloram in southern forest watersheds. In: Proceedings, 40th Annual Meeting Southern Weed Science Society; 1987 January 12-14; Orlando, FL. [Champaign, IL]: Southern Weed Science Society. 406. Abstract.

80. Wells, Martha J.M.; Michael, Jerry L. 1987. Recovery of picloram and 2,4-Dichlorophenoxyacetic acid from aqueous samples by reversed-phase solid-phase extraction. Analytical Chemistry. 59: 1739-1742.

81. Miller, James H.; Williamson, Max. 1987. Weeds in your woodlot? American Tree Farmer. 6(3): 8-9.

82. Michael, J.L. 1987. Mixtures for weed control in newly planted loblolly pine (Pinus taeda L.). In: Proceedings, 40th Annual Meeting Southern Weed Science Society; 1987 January 12-14; Orlando, FL. [Champaign, IL]: Southern Weed Science Society. 182-186.

83. Miller, James H. 1987. Chemical vs mechanical site preparation after fuelwood harvesting. In: Proceedings, 40th Annual Meeting Southern Weed Science Society; 1987 January 12-14; Orlando, FL. [Champaign, IL]: Southern Weed Science Society. 156-166.

84. Miller, James H. 1987. The use of herbicides in hardwood forestry. In: Proceedings Annual Meeting of the Hardwood Research Council; 1987 May 11-13; Memphis, TN. 31-52.

85. Boyer, William D. 1987. Role of competing vegetation in forest health. In: Proceedings of the 1986 Society of American Foresters National Convention; 1986 October 5-8; Birmingham, AL. Bethesda, MD: Society of American Foresters. 235-238.

86. Boyer, William D. 1987. Volume growth loss: a hidden cost of periodic prescribed burning in longleaf pine? Southern Journal of Applied Forestry. 11: 154-157.

87. Bush, P.B.; Neary, D.G.; McMahon, C.K.; Taylor, J.W. 1987. Effect of burning wood treated with lindane or chlorpyrifos for pine bark beetle control. Journal of Entomological Science. 22(2): 131-139.

88. Bush, P.B.; Neary, D.G.; McMahon, C.K.; Taylor, J.W. 1987. Suitability of hardwood treated with phenoxy and pyridine herbicides for firewood use. Archives of Environmental Contamination and Toxicology. 16: 333-341.

89. McMahon, C.K. 1987. Characteristics of emissions from prescribed fire. In: Proceedings, Air quality regulations and smoke management workshop. 1987 July 21-22; Atlanta, GA. 1-9.

90. McMahon, C.K. 1987. Is it safe to burn chemically treated forest fuels and wood products? In: Proceedings, Air quality regulations and smoke management workshop. 1987 July 21-22. Atlanta, GA. 1-5.

91. Segal, D.S.; Neary, D.G.; Best, G.R.; Michael; J.L. 1987. Effect of ditching fertilization, and herbicide application on groundwater levels and groundwater quality in a flatwood spodosal. In: Proceedings, Florida Soil and Crop Science Society 1986 Annual Meeting. 14-16 October 1986; Soil and Crop Science Society. 46: 107-112.

92. Wells, M.J.M.; Michael, J.L. 1987. Reversed-phase solid-phase extraction for aqueous environmental sample preparation in herbicide residue analysis. Journal of Chromatographic Science. 25: 345-350.

1988

93. Neary, D.G.; Bush, P.B.; McMahon, C.K.; Cantrell, R.T.; Taylor, J.W. 1988. Persistence of nine forestry pesticides in the surface of a typic quartzipsamment soil of the Ocala National Forest. In: Proceedings, Florida Soil and Crop Science Society 1987 Annual Meeting. 20-22 October 1987; Soil and Crop Science Society. 47: 127-134.

94. Miller, James H. 1988. Kudzu eradication trials with new herbicides. In: Proceedings, 41st Annual Meeting Southern Weed Science Society; 1988 January 18-20; Tulsa, OK. [Champaign, IL]: Southern Weed Science Society. 220-225.

95. Miller, James H. 1988. Hardwood control with directed sprays and thinline. In: Proceedings, 41st Annual Meeting Southern Weed Science Society; 1988 January 18-20; Tulsa, OK. [Champaign, IL]: Southern Weed Science Society. 143. Abstract.

96. Thomas, Mark W.; Gjerstad, D.H.; Minogue, P.J.; Miller, J.H.; Mitchell, R.J. 1988. Biological and economic comparison of mechanical and chemical alternatives for brush control in young pine stands. In: Proceedings, 41st Annual Meeting Southern Weed Science Society; 1988 January 18-20; Tulsa, OK. [Champaign, IL]: Southern Weed Science Society. 161. Abstract.

97. Michael, J.L.; Neary, D.G. 1988. Environmental fate of sulfometuron methyl in southern forest watersheds. In: Proceedings, 41st Annual Meeting Southern Weed Science Society; 1988 January 18-20; Tulsa, OK. [Champaign, IL]: Southern Weed Science Society. 219. Abstract.

98. Miller, J.H. 1988. Soil spot herbicides for single-stem hardwood control. Southern Journal of Applied Forestry. 12: 199-203.

99. Edwards, M. Boyd; Miller, James H. 1988. Please release me, let me grow! Forest Farmer 47(6):17-19.

100. Boyer, William D. 1988. Effects of site preparation and release on the survival and growth of planted bare-root and container-grown longleaf pine. Georgia Forestry Commission, Georgia Forest Research Paper. 76: 1-7.

101. Michael, J.L.; Neary, D.G. 1988. Sulfometuron methyl dissipation in southern forest watersheds. In Society of Environmental Toxicology and Chemistry Eight Annual Meeting; 1987 November 9-12. Pensacola, FL; Society of Environmental Toxicology and Chemistry: 134. Abstract.

102. Miller, James H. 1988. Herbicide technology: its present and future role in re-establishing southern pine plantations. In: Gresham, C.A., ed. 1988 Proceedings Second Rotation Plantation Establishment Workshop. Baruch Foundation, Georgetown, South Carolina: 26-38.

103. Miller, James H. 1988. Guidelines for kudzu eradication treatments. In: Miller, J.H.; Mitchell, R.J. eds. A manual on Ground Applications of Forestry Herbicides. U.S. Department of Agriculture, Forest Service, Southern Region, Management Bulletin R8-MB 21. Chapter 6.

104. Miller, James H. 1988. Herbicide applications with ground machines. In: Miller, J.H.; Mitchell, R.J. eds. A manual on Ground Applications of Forestry Herbicides. U.S. Department of Agriculture, Forest Service, Southern Region, Management Bulletin R8-MB 21. Chapter 3.

105. Williamson, Max; Miller, James H. 1988. Handcrew application methods for woody plant control. In: Miller, J.H.; Mitchell, R.J. eds. A manual on Ground Applications of Forestry Herbicides. U.S. Department of Agriculture, Forest Service, Southern Region, Management Bulletin R8-MB 21. Chapter 2.

106. U.S. Department of Agriculture, Forest Service; Southern Station; Southern Region. 1988. A manual on ground applications of forestry herbicides. Miller, J.H.; Mitchell, R.J. eds. U.S. Department of Agriculture, Forest Service, Southern Region, Management Bulletin R8-MB 21.

1989

107. Michael, J.L.; Neary, D.G.; Wells, M.J.M. 1989. Picloram movement in soil solution and streamflow from a coastal plain forest. Journal of Environmental Quality. 18(1): 89-95.

108. Michael, J.L. 1989. Low imazapyr concentrations in streamflow from forest sites. In: Proceedings, 42nd Annual Meeting Southern Weed Science Society; 1989 January 16-18; Nashville, TN. [Champaign, IL]: Southern Weed Science Society. 213.

109. Miller, James H. 1989. Herbicide treatments can improve your forest. Forest Farmer. 48(5):25-28.

110. Miller, James H.; Bishop, Larry. 1989. Optimum timing for ground-applied forestry herbicides in the south. Management Bulletin R8-MB 28, Management Bulletin R-8 MB28, U.S. Department of Agriculture, Forest Service; Cooperative Forestry Technology Update. 2 p.

111. Boyer, William D. 1989. Response of planted longleaf pine bare-root and container stock to site preparation and release: fifth-year results. In: Proceedings Fifth Biennial Southern Silvicultural Research Conference, 1988 November 1-3; Memphis, TN. Gen. Tech. Rep. SO-74. New Orleans, LA: U.S. Department of Agriculture, Forest Service: 165-168.

112. McMahon, C.K.; Bush, P.B. 1989. Herbicide residues in forest fire smoke--a review. In: Proceedings, 42nd Annual Meeting Southern Weed Science Society; 1989 January 16-18; Nashville, TN. [Champaign, IL]: Southern Weed Science Society. 171. Abstract.

113. Neary, D.G.; Michael, J.L. 1989. Forestry herbicide environmental risks--an EIS perspective. In: Proceedings, 42nd Annual Meeting Southern Weed Science Society; 1989 January 16-18; Nashville, TN. [Champaign, IL]: Southern Weed Science Society. 209. Abstract.

114. Miller, J.H.; Zutter, B.R. 1989. A region-wide study comparing woody vs. herbaceous competition on loblolly pine growth. In: Proceedings, 42nd Annual Meeting Southern Weed Science Society; 1989 January 16-18; Nashville, TN. [Champaign, IL]: Southern Weed Science Society. 223. Abstract.

115. Thomas, M.W.; Miller, J.H.; Mitchell, R.J.; Minogue, P.J.; Gjerstad, D.M. 1989. Biological and economic comparison of mechanical and chemical alternatives for brush control in young pine stands-second year results. In: Proceedings, 42nd Annual Meeting Southern Weed Science Society; 1989 January 16-18; Nashville, TN. [Champaign, IL]: Southern Weed Science Society. 247. Abstract.

116. Neary, D.G.; Michael, J.L. 1989. Effect of sulfometuron methyl on ground water and stream quality in coastal plain forest watersheds. Water Resources Bulletin. 25(3): 617-623.

117. Neary, D. G.; Michael, Jerry L. 1989. Effects of Herbicides on Soil Productivity and Water Quality. In: Final Environmental Impact Statement; Vegetation Management in the Coastal Plain/Piedmont, Appendices, Volume II. Management Bulletin R8-MB 23; U.S. Department of Agriculture, Forest Service, Southern Region. January 1989.

1990

118. McMahon, Charles K. 1990. Environmental Aspects of Residential Fuelwood Use. Presented at Improving the Environment Through Forest Products Research, Forest Products Research Conference. 1989 October 3-5; Madison, WI: 4p.

119. McMahon, Charles K.; Bush, P. B. 1990. A Low Cost Sampler for Monitoring Worker Exposure to Herbicide Residues in Forest Fire Smoke. In: Proceedings of the 1990 EPA/AWMA International Symposium on Measurement of Toxic and Related Air Pollutants. 1990 April 30-May 4; Research Triangle Park, NC: 498-505.

120. Boyer, William D.; White, John B. 1990. Natural Regeneration of Longleaf Pine. In: Proceedings of the Symposium on the Management of Longleaf Pine; 1989 April 4-6; Long Beach, MS. Gen. Tech. Rep. SO-75. New Orleans, LA: U.S. Department of Agriculture, Forest Service: 94-113.

121. Boyer, William D. 1990. Growing-Season Burns for Control of Hardwoods in Longleaf Pine Stands. Research Paper. New Orleans, LA: U.S. Department of Agriculture, Forest Service: 26 p.

122. Michael, Jerry L.; Neary, Daniel G. 1990. Fate and Movement of Herbicides on Forest Sites in the Southern United States of America. Presented at the I.U.F.R.O.-Division of I-Project Group P1.13-00 "Herbicides in Forestry" International Meeting. Nancy, France; 22-26 May 1989.

123. Michael, Jerry; Neary, Dan; Gjerstad, Dean; D'Anieri, Peter. 1990. Use, Fate, and Risk Assessment of Forestry Herbicides in the Southern United States. In: Proceedings of IUFRO XIX World Congress; 1990 August 5-11; Montreal, Canada. Montreal, Canada: Canadian International Union of Forestry Research Organizations: Vol. 2, 300-311.

124. Bush, P. B.; Michael, J.; Neary, D. G.; Miller, K.V. 1990. Effects of Hexazinone on Groundwater Quality in the Coastal Plain. In: Proceedings Southern Weed Science Society Risk/Benefit: A Way of life 43rd annual meeting; 1990 January 15-17; Atlanta, GA. Champaign, IL: Southern Weed Science Society: 184-194.

125. Miller, James H. 1990. Spray Distribution of Boomless Nozzles: The Boomjet 5880, Radiarc and Boom Buster. In: Proceedings, 43rd Annual Meeting Southern Weed Science Society; 1990 January 15-17; Atlanta, GA. Champaign, IL: Southern Weed Science Society: 203-214.

126. Pancake, Dale C.; Miller, James H. 1990. Streamline Rate and Timing with Triclopyr and Imazapyr on Seven Woody Species. In: Proceedings, 43rd Annual Meeting Southern Weed Science Society; 1990 January 15-17; Atlanta, GA. Champaign, IL: Southern Weed Science Society: 222. Abstract.

127. Miller, James H. 1990. Herbaceous Weed Control Trials with a Planting Machine Sprayer and a Crawler-Tractor Sprayer--Fourth Year Pine Response. In: Proceedings, 43rd Annual Meeting Southern Weed Science Society; 1990 January 15-17; Atlanta, GA. Champaign, IL: Southern Weed Science Society: 233-244.

128. Thomas, Mark W.; Miller, J. H.; Mitchell, R. J.; Minogue, P. J.; Gjerstad, D. M. 1990. Biological and Economic Comparison of Mechanical and Chemical Alternatives for Brush Control in Young Pine Stands--Third Year Results. In: Proceedings, 43rd Annual Meeting Southern Weed Science Society; 1990 January 15-17; Atlanta, GA. Champaign, IL: Southern Weed Science Society: 281. Abstract.

129. Miller, James H. 1990. Streamline Basal Application of Herbicide for Small-Stem Hardwood Control. Southern Journal of Applied Forestry 14: 161-165.

130. Miller, James H. 1990. Directed Foliar Sprays of Forestry Herbicides for Loblolly Pine Release. Southern Journal of Applied Forestry 14: 199-206.

1991

131. Fischer, Joseph B.; Michael, Jerry L. 1991. Development of Analytical Methods for Metsulfuron Methyl Herbicide in Forest Environment Samples. In: Proceedings, Symposium on Current Research in the Chemical Sciences Third Annual Southern Station Chemical Sciences Meeting, 1990 February 7-8; Alexander, LA: 69-76.

132. McMahon, Charles K.; Bush, P. B. 1991. Evaluation of Worker Respiratory Exposure to Herbicide Residues in Prescribed Fire Smoke. In: Proceedings, Symposium on Current Research in the Chemical Sciences Third Annual Southern Station Chemical Sciences Meeting, 1990 February 7-8; Alexandria, LA: 77-83.

133. Nelson, Larry R. Dr.; Miller, James H. Dr. 1991. Forestry Herbicide Technology. Forest Farmer 50(28):73-76.

134. McMahon, Charles K.; Bush, P.B. 1991. Evaluation of Worker Respiratory Exposure to Herbicide Residues in the Smoke from Prescribed Fires in the South. Technical Release 91-R-30, American Pulpwood Association Inc. 2 p.

135. Boyer, W.D. 1991. Pinus palustris Mill., Longleaf Pine, Pinaceae, Pine family. In: Silvics of North America I. Conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture: 405-412.

136. Kossuth, Susan V.; Michael, J.L. 1991. Pinus glabra Walt., Spruce Pine, Pinacea, Pine family. In: Silvics of North America I. Conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture: 355-358.

137. Miller, James H. 1991. Ailanthus altissima (Mill.) Swingle, Ailanthus, Simaroubaceae, Quassia family. In: Silvics of North America I. Conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture: 101-104. Vol. 2.

138. Miller, James H.; Glover, Glenn R. eds. 1991. Standard Methods for Forest Herbicide Research. Southern Weed Science Society; Champaign, IL. 68 p.

139. Zedaker, Shepard M.; Miller, James H. 1991. Measurement of Target and Crop Species. 1991. In: Miller, James H.; Glover, Glenn R. eds. Standard Methods for Forest Herbicide Research. Southern Weed Science Society; Champaign, IL. 22-40. Chapter 4.

140. Miller, James H. 1991. Application Methods for Forest Herbicide Research. In: Miller, James H.; Glover, Glenn R. eds. Standard Methods for Forest Herbicide Research. Southern Weed Science Society; Champaign, IL. 45-60. Chapter 6.

141. Miller, J.H.; Edwards, M.B. 1991. A Comparison of Herbicides for Loblolly Pine Release. In: Proceedings Southern Weed Science Society Perception: Fact or Fiction 44th annual meeting; 1991 January 14-16; San Antonio, TX. [Champaign, IL]: Southern Weed Science Society. 274. Abstract.

142. Edwards, M.B.; Miller, J.H. 1991. A Comparison of Site Preparation Herbicides--5 Year Pine Growth. In: Proceedings Southern Weed Science Society Perception: Fact or Fiction 44th annual meeting; 1991 January 14-16; San Antonio, TX. [Champaign, IL]: Southern Weed Science Society. 256. Abstract.

143. Michael, J.L.; Neary, D.G.; Fischer, J.; Gibbs, H. 1991. Metsulfuron in Surface Groundwater of a North Florida Flatwoods. In: Proceedings Southern Weed Science Society Perception: Fact or Fiction 44th annual meeting; 1991 January 14-16; San Antonio, TX. [Champaign, IL]: Southern Weed Science Society. 233-237.

144. Miller, J.H. 1991. Moving Towards Research Standardization in Forest Vegetation Management. In: Proceedings Southern Weed Science Society Perception: Fact or Fiction 44th annual meeting; 1991 January 14-16; San Antonio, TX. [Champaign, IL]: Southern Weed Science Society. 238. Abstract.

145. McMahon, C.K. 1991. Evaluation of Worker Respiratory Exposure to Herbicide Residues in the Smoke from Prescribed Fires. In: American Industrial Hygiene Conference & Exposition "Pioneering Change in a Global Environment" Abstract Book: 1991 May 18-24; Salt Lake City, UT. [Salt Lake City, UT]: American Industrial Hygiene Association and American Conference of Governmental Industrial Hygienists: 68.

146. Miller, James H.; Mitchell, Robert J. 1991. Common Herbicide Terms and Concepts. Forest Farmer 51(1):6.

147. Miller, James H. 1991. Control Kudzu on Your Land. Forest Farmer 51(1):7-11.

148. Boyer, William D. 1991. Effects of A Single Chemical Treatment on Long-term Hardwood Development in a Young Pine Stand. In: Coleman, Sandra S.; Neary, Daniel G., comps., eds. Proceedings of the 6th biennial southern silvicultural research conference; 1990 October 30-November 1; Memphis, TN. Gen. Tech. Rep. 70. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 599-606. Vol. 2.

149. Everest, John W.; Miller, James H.; Ball, Donald M.; Patterson, Michael G. 1991. Kudzu In Alabama. Circular ANR-65. Alabama Cooperative Extension Service. 8p.

150. Michael, J.L.; Neary, Daniel G. 1991. Fate and Transport of Forestry Herbicides in the South: Research Knowledge and Needs. In: Coleman, Sandra S.; Neary, Daniel G., comps., eds. Proceedings of the 6th biennial southern silvicultural research conference; 1990 October 30-November 1; Memphis, TN. Gen. Tech. Rep. 70. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 641-649. Vol. 2.

151. Miller, James H.; Zutter, Bruce R.; Zedaker, Shepard M. [and others]. 1991. A Regional Study on the Influence of Woody and Herbaceous Competition on Early Loblolly Pine Growth. Southern Journal of Applied Forestry 15(1991):169-179.

152. Miller, James H. 1991. Forest Herbicide Benefits and Developments for Intensive Southern Pine Culture. In: Stokes, Bryce J.; Rawlins, Cynthia L., eds., Proceedings of the Forestry and Environment... Engineering Solutions; 1991 June 5-6; New Orleans, LA. ASAE Publication 09-91. St. Joseph, MI: American Society of Agricultural Engineers. 129-138.

1992

153. Bonsi, C.; Rhoden, E.; Woldeghebriel, A.; Mount, P.; [an others] Kudzu-goat Interactions--A Pilot Study. 1992. In: Solaiman, Sandra G.; Hill, Walter A. eds. Using Goats to Manage Forest Vegetation, A Regional Inquiry. Tuskegee, AL: Tuskegee University Agricultural Experiment Station: 84-88.

154. Boyer, W.D. 1992. Effects of A Single Chemical Treatment on Long-term Hardwood Development in a Young Pine Stand. In: Coleman, Sandra S.; Neary, Daniel G., comps., eds. Proceedings of the 6th biennial southern silvicultural research conference; 1990 October 30-November 1, Memphis, TN. Gen. Tech. Rep. 70. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 599-606. Vol. 2.

155. Farrar, Robert M.; Boyer, William D. 1992. Managing Longleaf Pine Under The Selection System - Promises and Problems. In: Coleman, Sandra S.; Neary, Daniel G., comps., eds. Proceedings of the 6th biennial southern silvicultural research conference; 1990 October 30-November 1, Memphis, TN. Gen. Tech. Rep. 70. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 357-368. Vol. 1

156. McMahon, Charles K.; Bush, P.B. 1992. No herbicide residues found in smoke from prescribed fires. Management Bulletin R8-MB-56. Atlanta, GA: U.S. Department of Agriculture, Southern Region. 2 p.

157. McMahon, Charles K.; Bush, Parshall B. 1992. Forest worker exposure to airborne herbicide residues in smoke from prescribed fires in the Southern United States. American Industrial Hygiene Association Journal 53(4): 265-272.

158. Mitchell, Robert J.; Miller, James H. 1992. Forest Herbicide Safety. Forestry Farmer 51(7): 6-9, 30.

159. Miller, J.H.; Boyer, W.D. 1992. Effect of Repeated Biennial Burns on Soil Properties and Foliar Nutrients in Longleaf Pine Stands. In: Agronomy Abstracts; 1991 October 27 - November 1, Denver, CO. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America: 353.

160. Miller, James H.; Zutter, Bruce R.; Zedaker, Shepard M. [and others]. 1992. Vegetation Management Effects on Early Successional Trends in Loblolly Pine Plantations of the Southeastern USA. In: International Conference on Forest Vegetation Management "Ecology, Practice and Policy" Program and Abstracts: 1992 April 27 - May 1, Auburn University, AL. [Auburn University, AL]: Auburn University, School of Forestry and International Union of Forestry Research Organizations: 48.

161. Huamei, Xu; Zhongza, Qiu; Miller, James H. 1992. Hexazinone Use for Forest Vegetation Management in Southern China. In: International Conference on Forest Vegetation Management "Ecology, Practice and Policy" Program and Abstracts: 1992 April 27 - May 1, Auburn University, AL. [Auburn University, AL]: Auburn University, School of Forestry and International Union of Forestry Research Organizations: 53.

162. Zedaker, S.M.; Gregoire, T.G.; Miller, J.H. 1992. Sample Size Needs for Forestry Herbicide Trials. In: International Conference on Forest Vegetation Management "Ecology, Practice and Policy" Program and Abstracts: 1992 April 27 - May 1, Auburn University, AL. [Auburn University, AL]: Auburn University, School of Forestry and International Union of Forestry Research Organizations: 65.

163. Webber, E.C.; Seesock, W.C.; Bayne, D.R.; Michael, J.L. 1992. Impact of hexazinone on bethic macroinvertebrates and fish in small streams [Abstract]. International Conference on Forest Vegetation Management "Ecology, Practice and Policy" Program and Abstracts: 1992 April 27 - May 1, Auburn University, AL. [Auburn University, AL]: Auburn University, School of Forestry and International Union of Forestry Research Organizations: 89.

164. McMahon, C.K. 1992. Herbicides and forest ecosystems - approaches to risk communication. In: Proceedings of the 45th Annual Meeting Southern Weed Science Society; 1992 January 20-22; Little Rock, AR. [Champaign, IL]: Southern Weed Science Society: 154-170.

165. Miller, J.H.; Coleman, T.L. 1992. Can a modular multiband radiometer be used to estimate young pine biomass and LAI? [Abstract]. In: Proceedings of the 45th Annual Meeting Southern Weed Science Society; 1992 January 20-22; Little Rock, AR. [Champaign, IL]: Southern Weed Science Society: 206 p.

166. Webber, E.C.; Seesock, W.C.; Bayne, D.R.; Michael, J.L. 1992. Impact of hexazinone on bethic macroinvertebrates and fish in small streams [Abstract]. In: Proceedings of the 45th Annual Meeting Southern Weed Science Society; 1992 January 20-22; Little Rock, AR. [Champaign, IL]: Southern Weed Science Society: 227 p.

167. Miller, J.H.; Xu, H.; Qiu, Z. 1992. Hexazinone uses in China's Southeastern forests [Abstract]. In: Proceedings of the 45th Annual Meeting Southern Weed Science Society; 1992 January 20-22; Little Rock, AR. [Champaign, IL]: Southern Weed Science Society: 233 p.

168. Michael, J.L.; Talley, K.L. 1992. Forest herbicide washoff from foliar applications [Abstract]. In: Proceedings of the 45th Annual Meeting Southern Weed Science Society; 1992 January 20-22; Little Rock, AR. [Champaign, IL]: Southern Weed Science Society: 236 p.

169. Qui, Z.; Miller, J.H. 1992. Chemical vs. mechanical site preparation for establishing loblolly and slash pine after intensive harvesting [Abstract]. In: Proceedings of the 45th Annual Meeting Southern Weed Science Society; 1992 January 20-22; Little Rock, AR. [Champaign, IL]: Southern Weed Science Society: 256 p.

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INFORMATION NOTE 92-1

A BIBLIOGRAPHY OF THE EFFECTS OF FOREST HERBICIDES ON AQUATIC ORGANISMS AND WATER QUALITY

by

Craig Ramsey

December 23, 1992

This past summer I did a literature search of the impacts of forest herbicides on water quality and aquatic organisms. I conducted the searches because I thought that the impact of herbicides on water quality and aquatic organisms was a high priority environmental issue for our members. I also wanted to get an update of all the studies that have been conducted in this area since the U. S. Forest Service did their literature review for their FEIS on Vegetation Management in 1988. The water quality literature search was actually initiated early in 1992 because an request for information from EPA nonpoint source pollution officials.

The public concern over wetlands, nonpoint source pollution, and water pollution has consistently been a high priority issue over the last two decades. As a result of this concern there is now a plethora of regulations to keep our waters "fishable and swimmable". Nonpoint source pollution (NPS) is the latest hot issue which will evolve into plenty of additional regulations. Filter strips will be one of the main preventative measures that could be used to protect our waterways and aquatic life. It is quite likely that regulatory agencies will be looking closely at what types of filter strips work, which filter strip widths work best, and which order of streams or size of pond should be protected.

As usual, there are few direct scientific studies which can help answer such questions as how wide should a filter strip be given different conditions and sites for herbicide use. However, there are studies that are related to this subject which deal with the effects of herbicides on water quality and aquatic organisms. Some experts, although, may argue the usefulness of these studies for our particular region, or that some of the studies are not "ecosystem" or real world research. I believe that these studies can provide at least partial answers to questions relating to filter strip use and preventing forest herbicide pollution in our waterways. Perhaps these studies will also help lessen the concerns of forest managers and provide evidence that they are not damaging our waterways when they use herbicides.

The report on the hexazinone/watershed project by Dr Jerry Michael with the U.S. Forest Service laboratory in Auburn is not available to the public yet. A study by Dr Cliff Webber, within that project, examined the impact of hexazinone on aquatic organisms in three watersheds. Dr Webber's conclusions from the 1992 Southern Weed Science Society Proceedings are included in my bibliography (Webber 1992). There is only one other ecosystem study in the South which has investigated the impacts of forest herbicides on aquatic organisms (Mayack, et al 1982). Dr Michael plans to focus his herbicide/environmental fate work on the cumulative effects of forest herbicides on watersheds and aquatic organisms, which will soon be critical issues in our region.

I have included a selected set of references for the effects of forest herbicides on aquatic organisms because many references were outdated or only slightly relevant to our uses. I included as many abstracts as the search contained, or that were in our library holdings. In the case where a journal article was in our library, but did not contain an abstract, I included a quote of their research

BIBLIOGRAPHY FOR FOREST HERBICIDES AND AQUATIC ORGANISMS RESEARCH

Abou-Waly, H., Abou-Setta, M.M., Nigg, H.N., and L.L. Mallory. 1991. Dose-response relationship of Anabaena flos aquae and Selenastrum capricornutum to atrazine and hexazinone using chlorophyll (a) content and carbon-14 uptake. Aquat Toxicol 20(3):195-204.

Atrazine and hexazinone were added to unicultural algal cultures of Anabaena flos-aquae (Lyng) (blue-green alga) and *Selenastrum capricornutum* (Printz) (green alga). Algal biomass was measured using chlorophyll (a) content and physiological activity was measured using ^{14}C uptake over 1, 3, 5 and 7 days. Untreated cultures increased in biomass over the first 5 days, leveling off after day 7. Control culture ^{14}C uptake per mg Chl (a) was highest on day 1 and declined over 7 days. A. flos-aquae biomass and ^{14}C uptake were inhibited by both herbicides on day 1 and began recovering on day 3 over concentration ranges of 0.1-1.05 ppm atrazine and 0.7-2 ppm hexazinone. ^{14}C uptake for both herbicide treatments was about half of the controls from day 1-3. *S. capricornutum* biomass and ^{14}C uptake were not significantly affected by concentrations up to 0.13 mg/l of atrazine; concentrations of 0.23-0.42 ppm reduced both biomass and ^{14}C uptake. Hexazinone concentrations of 0.03-0.1 ppm significantly reduced *S. capricornutum* biomass and ^{14}C over 7 days. Effects were generally related to herbicide dose.

Abou-Waly, H., Abou-Setta, M.M., Nigg, H.N., and L.L. Mallory. 1991. Growth response of freshwater algae, Anabaena flos-aquae and Selenastrum capricornutum to atrazine and hexazinone herbicides. Bull. Environ. Contam. Toxicol. 46:223-9.

The concentration of hexazinone which caused a 50% (LC_{50}) reduction in the chlorophyll content of green algae was measured over a 10 day period. The LC_{50} was .056 ppm for a 3 day duration, .085 for a 5 day duration, and .125 for a 7 day duration. The LC_{50} was also estimated for blue-green algae. The LC_{50} was 2.014 ppm for a 3 day duration, 2.375 ppm for a 5 day duration, and 2.752 ppm for a 7 day duration. After this time the algae recovered to its carrying capacity 10 days after treatment.

Amancio, S. 1976. Ultrastructural alterations induced by the herbicide picloram (technical grade 70%) on a planktonic alga dunaliella bioculata (volvocales). C. R. Hebd. Acad. Sci. Ser. D. 283:1337-1340.

Anderson, D., Cummin, J., Katz, M., LeGore, R., May, D.R., and K. Weitkamp. 1972. Effects on freshwater fish. J. Water Pollut. Contr. Fed. 44(6):1226-1250.

Literature on the effects of pesticides and herbicides and other water pollutants on freshwater fish was reviewed. Several reviews have been published on the ecological effects of pesticides in water. An international study of organochlorine residues was conducted by 17 laboratories. In a national monitoring program, DDT and dieldrin were found in most fish samples. Static bioassays indicated that on estuarine fish the descending order of toxicity of insecticides was endrin, DDT, dieldrin, aldrin, dioxathion,

Bettoli, P.W. and P.W. Clark. 1992. Behavior of sunfish exposed to herbicides: A field study. Environ. Tox. and Chem. 11:1461-1467.

An underwater closed-circuit video system was used to remotely monitor and record the behavior of bluegills (*Lepomis macrochirus*) and redear sunfish (*Lepomis microlophus*) guarding their nests before, during, and after applications of aquatic herbicides. Nests were sprayed to achieve a nominal concentration of 4 mg/L of either a dipotassium salt of endothall (Aquathol-K®), a dimethylamine salt of 2,4-dichlorophenoxyacetic acid (2,4-D), or water (control). No significant differences in rates of nest abandonment existed among the three treatments ($p>0.10$. Abandonment averaged 5.17 min for both species and herbicide treatments, whereas the herbicides persisted in the water column for at least 45 min. When abandonment occurred, congeners nearly always intruded on the nest to feed on eggs or fry. After spraying, the adjusted mean frequency of rim circling, fanning, and agonistic behaviors exhibited by bluegills guarding eggs did not differ among the three treatments ($p \geq 0.35$). These results suggest the two herbicides will not elicit pronounced shifts in reproductive behavior of sunfish when they are properly applied.

Bovey, Jr., R.W. and C.J. Scifres, Jr. 1971. Residual characteristics of picloram in grassland ecosystems. Texas Agr. Exp. Sta. Bull. 1111:24.

<u>Picloram</u> (4-amino-3,5,6-trichloropicolinic acid) applied alone or in combination with 2,4,5-trichlorphenoxyacetic acid (2,4,5-T) has potential for control of many herbaceous weeds and wood plants in grasslands. New data on rates and routes of picloram dissipation are reported for Texas grasslands. Picloram is susceptible to photodecomposition and is mobile within the ecosystem, following the movement of water. Movement of picloram over the soil surface is governed primarily by intensity of rainfall, time-lapse from application to the first rain, rate of picloram applied, density and botanical composition of vegetation cover, soil texture, and slope of land. In North Texas, 17 ppb of picloram occurred in surface runoff after application of 0.25 pound/acre to highly permeable, sparsely vegetated soils. Applications of one and two pounds/acre to rangeland in South and Southwest Texas did not result in detectable residues in domestic water wells. Dilution in soil may be one of the most important, practical means of dissipating picloram. Vegetative growth of sensitive field crops would probably not be reduced by a single irrigation of water containing 1-4 ppb of picloram. <u>Large columes of water containing 4 ppb applied to seedlings would likely reduce crop growth, while residues of 10 ppb or more in irrigation water could severely affect the growth of some sensitive crop seedlings.</u> Picloram residues in the environment do not appear harmful to mammals, fish, birds, or insects.

Bowmer, K.H. 1986. Rapid biological assay and limitations in macrophyte ecotoxicology a review. Aust. J. Mar. Freshwater Res. 37(2):297-308.

Bowmer, K.H. 1990. Herbicides in water economics or environment. Aust. CSIRO Inst. Nat. Resour. Environ. Div. Water Resour. Tech. Memo. 0(90-4):1-19.

maximum herbicide concentrations in runoff and results of acute tests indicated that Ramrod®, ME4 Brominal®, and Lasso® pose the greatest direct risk to midge larvae during a storm event.

Buikema, A.L., Benfield, E.F., and B.R. Niederlehner. 1981. Effects of pollution on freshwater invertebrates. J. Water Pollut. Control Fed. 53(6):1007-1015

Studies of pollutant effects on freshwater invertebrates are reviewed, and a comprehensive bibliography of the literature is provided. Separate sections discuss pertinent review articles, methods, microcosms, and communities. Specific studies are cited that investigated toxicity to cladocera, other zooplankters, amphipods, decapods, insects, molluscs, protozoa, and other organisms. Of these investigations, many involve the effects of pesticides on nontarget freshwater aquatic invertebrates. Some of the pesticides that are specifically mentioned are Roundup (glyphosate), DDT, pentachloronitrobenzene, (quintozene), simazine, trifluralin, toxaphene, fenvalerate, cyanatryn, lindane, mirex, and dieldrin. Examples of toxic effects caused by exposure to pesticides include inhibition of filtering activity of the mollusc Anodonta cygnea by sublethal concentrations of insecticides, and the development of uncoordinated locomotor movement in the cladoceran Daphnia pulex when exposed to the triazine herbicide cyanatryn at 20 ppm for 15 min.

Butler, G.L. 1977. Algae and pesticides. In: Residue Reviews. Residues of Pesticides and Other Contaminants in the Total Environment, Vol. 66 (gunther, Francis A. and Jane Davies Gunther Ed.). VIII+212P. Springer-verlag: New York, N.Y., USA; Berlin, West Germany. pp. 19-62.

Byl, T.D. and S.J. Klaine. 1990. Peroxidase activity as an indicator of sublethal strees in the aquatic plant hydrilla-verticillata royle. In: Plants for Toxicity Assessment: Second Volume; Symposium, April 23-24, 1990, San Francisco, CA, USA (Gorsuch, J. W., et al. Eds.). ASTM (American Society for Testing Materials) Special Technical Publications, 1115. VII+401p.

Camper, N.D. Biochemical and residual properties of pesticides. Clemson University/Plant Pathology & Physiology, Clemson, South Carolina 29634. Fedrip Database, National Technical Information Service (NTIS).

Determine the metabolic fate of aldicarb, avermectin, chlorpyrifos, Diquat, EDB, pyrethroids and related pesticides in insects, plants, and soil-water systems. Determine the dissipation and persistence of alachlor, atrazine, chlorpyrifos, hexazinone, norflurazon, nemacur, and pyrethroids in surface and vadose-zone soils and water. Degradation of selected radiolabeled herbicides and other pesticides in anaerobic aquatic sediments will be quantitatively determined with analytical techniques that include TLC and HPLC. The residue level and fate of diquat will be determined in sediment in treated reservoirs and in vitro experiments. Clomazone was degraded in tobacco callus and cell suspensioncultures with the formation of two degradation products during the early phase of incubation. Resistant callus tissue never released the unknowns into the culture medium while the

Davis, W.S., and T.J. Denbow. 1988. Aquatic sediments. J. Water Pollut. Control Fed. 60(6):1077-1088.

Feng, J.C., Thompson, D.G., and P.E. Reynolds. 1990. Fate of glyphosate in a Canadian forest watershed: 1. Aquatic residues and off-target deposit assessment. J. Agric. Food Chem. 38(4):1110-1118.

Glyphosate and AMPA residues in oversprayed and buffered streams were monitored following application of ROUNDUP (2.0 kg/ha) to 45 ha of a coastal British Columbia watershed. Maximum glyphosate residues (stream water, 162 mug/L; sediments, 6.80 mug/g dry mass; suspended sediments, < 0.03 mug/L) were observed in two intentionally oversprayed tributaries, dissipating to < 1 mug/L within 96 h postapplication. Buffered streams were characterized by very low glyphosate residue levels (2.4-3.2 mug/L in streamwater). Results of the off-target deposit assessment indicated < 0.01% of applied glyphosate at 8 m from the spray boundary. Increases in residue levels were observed in relation to the first storm event postapplication. Ratios of maximum stream water concentrations of glyphosate observed in buffered and oversprayed tributaries relative to literature toxicity values indicated a substantial margin of safety under either operational or worst case scenarios.

Fleming, W.J., Ailstock, M.S., and J.J. Momot. 1990. Norman cmresponse of Sago pondweed a submerged aquatic macrophyte to herbicides in laboratory culture systems. In: ASTM (American Society for Testing Materials) Special Technical Publications, 1115. Plants for Toxicity Assessment: Second Volume (Gorsuch, J.W., et al. (ed.). San Francisco, CA, April 23-24, 1990. VII+401p.

Fogels, A. and J.B. Sprague. 1977. Comparative short-term tolerance of zebrafish, flagfish, and rainbow trout to five poisons including potential reference toxicants. Water Res. 11(9):881-818.

Zebrafish (Brachydanio rerio) and flagfish (Jordanella floridae) were evaluated as potential standard species for aquatic bioassays in Canada by comparing their short-term tolerance to that of rainbow trout (Salmo gairdneri). When threshold or 10 day LC50 for rainbow trout were assigned a value of 1.0, corresponding values for zebrafish and flagfish were, respectively: copper sulfate, 1.6, 7.2; sodium pentachlorophenate, 4.7, 7.6; phenol, 2.5, 3.1; picloram, 1.6, 0.55; and dodecyl sodium (DSS) sulfate, 2.8, 2.4. On the average, zebrafish were 2.6 times as tolerant as trout, and flagfish 4.2 times. Ratios of zebrafish/trout LC50 were considerably less variable than flagfish/trout LC50. Considering the known variable response of rainbow trout and a maximum ratio of only 7.6 for exotic/trout LC50, responses of zebrafish and flagfish were judged not sufficiently different from those of rainbow trout to discount either exotic species from further consideration as a potential standard test-fish. As a reference toxicant, sodium pentachlorophenate presented difficulties with analysis and availability. DSS showed no threshold of acute lethality for trout and 5 yr old DSS had about 1/3 the toxicity of 1 yr old DSS. Phenol met all criteria considered for a reference toxicant.

mutagenesis. Anaerobic growth was not possible on any of the fermentable sugars. All the microalgae were sensitive to the photosystem II inhibitors diuron and atrazine and the 70S ribosome inhibitors erythromycin and streptomycin. However, the diatoms were insensitive to spectinomycin and sulfometuron methyl. Information about drug sensitivities permitted the selection of drug resistant mutants. Mutagenized cultures produced colonies when plated on media containing drug concentrations that were growth-inhibiting for wild-type cultures. Mutations were recovered in Monoraphidium, Nannochloropsis, and Navicula species.

Goldsborough, L.G. and A.E. Beck. 1989. Rapid dissipation of glyphosate in small forest ponds. Arch. Environ. Contam. Toxicol. 18(4):537-544.

Glyphosate was applied to the water surface of four small boreal forest ponds and six *in situ* microcosms at a rate of 0.89 kg a.i./ha. Water samples collected over a period of up to 255 days were analyzed for glyphosate and its primary metabolite aminomethylphosphonic acid (AMPA). Glyphosate dissipated rapidly from all ponds with first order half-lives ranging from 1.5 to 3.5 days. The slowest dissipation rate occurred in the pond with the most calcareous water and sediments. Glyphosate remained at or above the treatment concentration in microcosms containing only water but decreased rapidly in the presence of sediments. AMPA levels in ponds and microcosms were consistently low. Concentrations on microcosm wall samples were temporally variable, probably a result of adsorption to periphytic biofilms. Glyphosate in the sediments of treated microcosms generally increased with time during the period of observation. These results confirm that glyphosate dissipates rapidly from the surfaces waters of lentic systems, and suggest that sediment adsorption or biodegradation were the major means of glyphosate loss from the water column.

Goldsborough, L.G. and D.J. Brown. 1988. Effect of glyphosate (Roundup formulation) on periphytic algal photosynthesis. Bull. Environ. Contam. Toxicol. Vol. 41(2):253-60

Haag, K.H. 1986. Effects of herbicide application on mortality and dispersive behavior of the water hyacinth weevils neochetina-eichhorniae and neochetina-bruchi coleoptera curculionidae. Environ. Entomol. 15(6):1192-1198.

Toxicities of commonly used water hyacinth herbicides and additives to water hyacinth weevils, *Neochetina eichhorniae* Warner and *N. bruchi* Hustache, were tested in the laboratory. Weevils were either sprayed while on water hyacinth plants or dipped directly into the compounds tested. No significant mortality resulted from exposure to 2,4-D, diquat, glyphosate, or additives including a surfactant and a polymer. Exposure to an inverting oil, and its primary component d'limonene, resulted in significant mortality of both species at concentrations tested. Effects of herbicide exposure on flight muscle development seemed to be related to time of year at which exposure occurred. Effects of herbicide application on dispersive behavior were determined by placing marked weevils on artificial weed mats in the field. Mats were subsequently sprayed with a standard concentration of 2,4-D. Weevils consistently migrated from sprayed, dying plants to

well as 10x and 100x field dose resulted in no mortality to rainbow trout in field streams. Results indicate that operational spraying with this herbicide for weed control should not be detrimental to rainbow trout populations. Improper use or accidental spills of Roundup could be avoided by rainbow trout and should not be lethal if diluted in a moderately-flowing stream.

Holck, A.R. and C.L. Meek. 1987. Dose-mortality responses of crawfish and mosquitoes to selected pesticides. J. Am. Mosq. Control Assoc. 3(3):407-411.

A study was conducted to determine the toxicities (LC_{50}s) of several pesticides on the commercially important red swamp crawfish, *Procambarus clarkii*, and 3 mosquito species common in Louisiana ricelands - *Anopheles quadrimaculatus, Culex salinarius* and *Psorphora columbiae*. Pesticides tested in laboratory bioassays included *Bacillus sphaericus, B. thuringiensis* var. *israelensis*, bendiocarb, glyphosate, isostearyl alcohol, malathion, propoxur, resmethrin synergized with piperonyl butoxide (PBO) and thiobencarb. Isostearyl alcohol was the least toxic compound to crawfish, with a LC_{50} of >10,000 ppm, while resmethrin + PBO (1:3 ratio) was the most toxic with a LC_{50} of 0.00082 ppm. The herbicides glyphosate and thiobencarb were the least toxic compounds for the mosquito species tested, while *B. t.* var. *israelensis* and resmethrin + PBO were the most toxic.

Holdway, D.A., and D.G. Dixon. 1988. Acute toxicity of permethrin or glyphosate pulse exposure to larval white sucker (Catostomus commersoni) and juvenile flagfish (Jordanella floridae) as modified by age and ration level. Environ. Toxicol. Chem. 7(1):63-68.

A factorial design was used to determine the effects of age (2, 4, and 8 d for flagfish; 13, 20, and 26 d for white sucker)and ration (fed or unfed) on the acute toxicity of permethrin pulse exposure. A similar design was used to evaluate the acute toxicity of glyphosate to flagfish. Relative tolerance was assessed by determining the 2-h pulse-exposure concentration causing 50% mortality (PE LC50) over the subsequent 96 h. Age at exposure and the presence or absence of food modified the toxicity of permethrin to both flagfish and white sucker. White sucker were consistently less tolerant of permethrin than flagfish. Fed and unfed 8-d-old flagfish, as well as unfed, 2-d-olds, showed equivalent levels of permethrin tolerance, with respective 96-h PE LC50s of 0.57, 0.54, and 0.68 mg L-1. They were significantly less tolerant than 4-d-old unfed juveniles (2.97 mg L-1), which were in turn significantly less tolerant than 2- to 4-d-old fed juveniles, whose respective 96-h PE LC50s were 5.55 and 7.91 mg L-1. Unfed white suckers were less tolerant than fed white suckers at all ages tested. Unfed white suckers at 13 d (96-h PE LC50, 0.002 mg L-1) and 20 d (0.001 mg L-1) were significantly less tolerant than unfed fish at 26 d (0.172 mg L-1) and fed fish at 13 d (0.184 mg L-1), which were more tolerant than 20-d-old fed fish (0.010 mg L-1). Fed fish at 26 d of age were the most tolerant (3.668 mg L-1). Glyphosate proved to be relatively non-toxic to flagfish up to 30 mg L-1. No mortality was observed during the bioassays with 2- and 4-d-old fed and starved fish. Fed 8-d-olds (96-h PE LC20, 29.6 mg L-1)were significantly more tolerant of glyphosate than were unfed 8-d-olds (96-h PE LC20, 2.94 mg L-1). The sharply delineated periods of permethrin sensitivity are discussed with reference to the theory of saltatory ontogeny.

tolerance limit (TL_{50}) was calculated for each toxicant from data obtained by static bioassay. Some adult frogs (*Litoria ewingi* and *Limnodynastes tasmaniensis*) were subjected to greater concentrations of several of the toxicants. Toxicity varied greatly among the tadpoles exposed to various toxicants with fenoprop being the most toxic chemical tested, while no differences were observed in behavior or activity between the exposed and control adult frogs. A significant reduction occurred in the thermal tolerance of 1-2 wk old *A. brevis* exposed to subacute dosages of amitrole-T, picloram and 2,2-DPA (2,2-dichloropropionic acid).

Johnson, C.R. 1978. Herbicide toxicities in the mosquito fish, Gambusia affinis. Proc. R. Soc. Queensl. 89:25-28.

G. affinis were exposed to a range of concentrations of 11 herbicides, fenoprop, sodium arsenite, picloram, dicamba, 2,4-D, 2,4,5-T, paraquat, monosodium methyl arsonate, disodium methyl arsonate, anitrole T and 2,2-dichloropropionic acid(2,2-DPA). From data obtained through static bioassay, the median tolerance limit was calculated for each toxicant. Considerable variation was found in toxicity to G. affinis with the various herbicides, ranging from 0.35 ppm for 96 h exposure to fenoprop to 19.0 g/l for 96 h exposure to 2,2-DPA. Fenoprop, sodium arsenite and picloram, respectively, were most toxic and the least toxic compounds tested were amitrole T and 2,2-DPA.

Kafarov, R.S., Bakumenko, L.A., and D.N. Matorin. 1985. Effect of herbicides on photosynthetic reactions in plants and algae. Agrokhimiya 0(11):99-104.

Kenaga, E.E. 1982. Predictability of chronic toxicity from acute toxicity of chemicals in fish and aquatic invertebrates. Environ. Toxicol. Chem. 1(4):347-358.

The relationship of the acute LC50 of chemicals to their chronic toxicity for aquatic animals can be expressed as the acute chronic ratio (ACR). Based on ACR data accumulated from the literature, the size ranges of ACR for various chemicals were determined for different species. The relationship and significance of the size of the ACR for various species, LC50 values, bioconcentration factors, classes of chemicals and their uses and mode of toxic action are given. LC50 acute toxicity data (86%) were $<$ 2 orders of magnitude different from the chronic toxicity no-effect concentration for the same chemicals and species. Among the industrial organic chemicals (i.e., excluding pesticides and metals) the average ACR for 4 spp. of organisms was 12, and 93% of these ACR values were 25. Industrial organic chemicals had a higher percentage of ACR values $<$ 25 than pesticides and heavy metals. These data offer a statistical basis for the prediction of chronic toxicity from acute toxicity.

Kenga, E.E. 1969. Tordon herbicides--evaluation of safety to fish and birds. Down to Earth 25(1):5-9.

This paper reviews the literature and unpublished data on the toxicity of Tordon herbicides, which contain 4-amino-3-5-6- trichloropicolinic acid (picloram), to several species of fish and birds. The nine different formulations studied, some in mixture with

Korotkova, O.A. 1975. Pesticides and the environment. Heterocyclic compounds. (Analytical review). Khim. Sel'sk. Khoz. 13(11):64-76.

Studies on the persistence, metabolism, and toxicity of heterocyclic pesticides are reviewed. Picloram is highly persistent in soil, but is rapidly degraded by UV light in aqueous solutions. It does not suppress soil microorganisms, and has low toxicity in aquatic organisms. Benomyl is relatively rapidly degraded by UV light and heat, and in water and plants. Fenazaflor is hydrolyzed in water, blood plasma, and liver. Thiabendazole is persistent in water and in soil. Methylthiophanate is rapidly metabolized in soil and in plant material, and has very low toxicity in warm-blooded organisms. Carboxin is oxidized to sulfoxide in soil. It has an LD50 of 2.68-3.2 g/kg in rats, and shows slight accumulation in the organism. Bromacil, terbacil, lenacil, and dimethirimol are noted for their very low toxicity in warm-blooded organisms. Pyramin is rapidly metabolized in soil by microorganisms, and has low toxicity. Bentazon does not influence the soil biological activity. Sencor is hydrolyzed in soil.

Kreutzweiser, D.P., Kingsbury, P.D., and J.C. Feng. 1989. Drift response of stream invertebrates to aerial applications of glyphosate. Bull. Environ. Contam. Toxicol. 42:331-8.

If the drift increases of *Paraleptophlebia* sp. were due to glyphosate contamination, they occurred at much lower concentrations than would be expected, suggesting a lower level of toxicant perception or a particular susceptibility of this genus to glyphosate, especially when exposed to the herbicide in actual field applications. If the drift responses were attributable to the herbicide treatment, the impact was limited to *Paraleptophlebia* sp. since none of the other groups demonstrated a similar increase. Small postspray increases in drifting *Gammarus* sp. were inconclusive. This short term impact study has shown that when glyphosate was aerially applied to or near salmon nursery streams, it produced, at most, slight and ephemeral drift increases of one mayfly species.

Kreutzweiser, D.P., S.B. Holmes, and D.J. Behmer. 1992. Effects of the herbicides hexazinone and triclopyr ester on aquatic insects. Ecotox. and Env. Safety 23:364-374.

Experiments were conducted to measure acute lethal response of aquatic insects to hexazinone (Velpar L) and triclopyr ester (Garlon 4) in flow-through laboratory bioassays, and to determine lethal and behavioral effects of these herbicides on insects in outdoor stream channels. No significant mortality (X^2 $P > 0.05$) occurred in 13 test species exposed to hexazinone in laboratory flow-through bioassays (1-hr exposure, 48-hr observation) at the maximum test concentration of 80 ppm. The survival of insects exposed to 80 ppm hexazinone in outdoor stream channels was likewise unaffected. Significant drift ((X^2 $P > 0.001$) of *Isonychia* sp. occurred during a hexazinone treatment of the stream channels, but only at the maximum concentration of 80 ppm, and survival of the displaced *Isonychia* sp. was not affected. In flow-through bioassays with triclopyr ester, 10 of 12 test species showed no significant mortality at concentrations greater than 80 ppm. Survival of *Isogenoides* sp. and *Dolophilodes distinctus* was significantly affected at less than 80 ppm. Lethal concentrations were estimated by probit analysis of concentration-response data (1-hr exposure, 48-hr observation) for *Simulium* sp. (LC_{50} =

Luetjen, K., Girardet, I., Altenburger, R., Faust, M., and L.H. Grimme. 1988. The effect of glyphosate and phosphinothricin on single celled green algae. Communications of the Federal Biological Institute for Agriculture and Forestry Berlin-dahlem, No. 245. 46th German Plant Protection Convention; Regensburg, West Germany, October 3-7, 1988. XXVII+524P. Kommissionsverlag Paul Parey: Berlin, West Germany. 0(0):396.

Malik, J., Barry, G., and G. Kishore. 1989. The herbicide glyphosate. Biofactors 2:17-25.

Glyphosate has broad spectrum herbicidal activity against a wide range of annual and perennial weeds. The environmental properties of this herbicide such as its soil immobility, rapid inactivation and soil biodegradation are outstanding. This herbicide is practically non-toxic to non-plant life forms such as aquatic and avian species, animals and man. Metabolism studies with pure bacterial cultures indicate that glyphosate is metabolized to either aminomethylphosphonate and glyoxylate or sarcosine and phosphate in most bacteria. The enzyme C-P lyase, which catalyzes the cleavage of the carbon-phosphorus bond of phosphonates including glyphosate, appears to be complex, containing multiple subunits. Mode of action studies have demonstrated that glyphosate kills plants by inhibiting the enzyme 5-enolpyruvylshikimate-3-phosphate synthase, involved in the biosynthesis of aromatic compounds. The status of our understanding of these aspects of glyphosate is reviewed.

Marquis, L.Y., Comes, R.D., and C.P. Yang. 1981.Absorption and translocation of fluridone and glyphosate in submersed vascular plants. Weed Sci. 29(2):229-236.

The uptake and translocation of fluridone [1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl] 4(1H)-pyridinone] were examined in sago pondweed (*Potamogeton pectinatus* L.) and Richardson pondweed [*Potamogeton richardsonii* (Ar. Benn.) Rydb.]. Root and shoot tissues of both species were isolated from each other with wax barriers and treated individually with 1.0 ppm ^{14}C-fluridone. Both tissues bioconcentrated fluridone, but the amount absorbed represented 1% or less of the total herbicide available. Limited root-to-shoot translocation occurred, but shoot-to-root transport was negligible. In contrast to fluridone, highly mobile glyphosate [N-(phosphonomethyl) glycine] translocated from the shoots to the roots in sago pondweed. No metabolism of fluridone was detected in sago pondweed. (Author abstract by permission)

Mayack, D.T., Bush, P.B., Neary, D.G., and J.E. Douglass. 1982. Impact of hexazinone on invertebrates after application to forested watersheds. Arch. Environ. Contam. Toxicol. 11(2):209-17

The impact of the herbicide, hexazinone, was assessed on aquatic macrophytes, aquatic and terrestrial invertebrate communities within forested watersheds in the Piedmont region of Georgia. Four replicate watersheds received hexazinone on April 23, 1979, and were subsequently monitored for eight months. Residue levels in terrestrial invertebrates were a maximum of two orders of magnitude greater than comparable levels (0.01 to 0.18 ppm) found in forest floor material. Aquatic organisms in a second order

unicellular green algae, fish muscle, or rat liver. A more sensitive electron microscope assay procedure for herbicide-membrane interaction was also developed with indications that animals and algae lack the biochemical mechanisms required for these organisms to respond to 2,4-D or related herbicides. For brush control along agricultural drainage ditches, 2,4-D alone is of limited effectiveness, Silvex as an ester can not be sprayed directly on the water, and application of dicamba appears to be more effective in spring than in the fall. (Author abstract by permission)

Nakayama, H. 1976. Recent topics on herbicides. Chem. Reg. Plants 11(1):9-18

After describing the present status of herbicides in Japan, their effects in combination, and the mechanism of their action, the residue problems of herbicides were introduced. Although many kinds of herbicides are decomposed swiftly in soil, some of them, e.g., atrazine, dichlobenil, diuron, fenac, monuron, neburon, picloram, propazine, simazine, and trichloroacetic acid remain more than a year in soil, and the residues damage crops planted in the next season. However, it is said that herbicides do not severely affect the soil organisms, except for bacteria concerning nitration. The contamination of lake sediments by the runoff of herbicide from fields remained for 120 days to 3-8 years in some cases, with possible damage to the livers of small fish in the lake (2,4-D, MCPA, DNOC, PCP, simazine, paraquat, and diquat).

Naqvi, S.M. and R.H. Hawkins. 1989.Responses and LC-50 values for selected microcrustaceans exposed to spartan malathion sonar weedtrine D and oust pesticides. Bull. Environ. Contam. Toxicol. 43(3):386-393.

Oust® herbicide seems to be the safest one among those tested. It is highly unlikely that the ambient water concentration of this compound would ever exceed 1000 ppm. Similarly, Sonar® herbicide might pose less problem to aquatic organisms due to its tendency to be adsorbed by the organic matter and soil particles, rapid uptake by plant-tissue and its half-life of 14 days or less in the field conditions (Muir et al. 1980). The reported LC_{50} for *Daphnia magna* is 6.3 mg/L (Waldrep & Taylor 1976). *Alonella* sp. (cladocerans) of our study were more than twice as tolerant as *Daphnia magna*.

Newton, M., Howard, K.M., Kelpsas, B.R., Danhaus, R., Lottman, C.M., and S. Dubelman. 1984. Fate of glyphosate in an Oregon (USA) forest ecosystem. J. Agric. Food Chem. 32(5):1144-1151.

Glyphosate herbicide residues and metabolites were evaluated in forest brush field ecosystems in the Oregon Coast Range aerially treated with 3.3 kg/ha glyphosate. Deposits were recorded at various canopy depths to determine interception and residues in foliage, litter, soil streamwater, sediments and wildlife for the following 55 days. The half-life of glyphosate ranged from 10.4 to 26.6 days in foliage and litter and twice as long in soil. The treated stream peaked at 0.27 mg/l and decreased rapidly; concentrations were higher in sediment than in water and persisted longer. Coho salmon fingerlings did not accumulate detectable amounts. Exposure of mammalian herbivores, carnivores and omnivores and retention of herbicide seemed to vary with food preference; however, all

Reinert, K.H. 1989.Environmental behavior of aquatic herbicides in sediments. In: Symposium on Reactions and Movement of Organic Chemicals in Soils held at the 1987 Annual Meeting of the American Society of Agronomy and the Soil Science Society of America, Atlanta, Georgia, USA, November 30-December 1, 1987. SSSA Spec. Publ. (Soil Sci. Soc. Am.) Ser. 0(22):335-348.

Rhodes, R.C. 1980. Studies with ^{14}C labeled hexazinone in water and bluegill sunfish. J. Agric. Food Chem. 28(2):306-310.

^{14}C residues in bluegill sunfish exposed to water containing [^{14}C]hexazinone at 0.01 and 1.0 ppm for 4 wk were found to plateau after 1-2 wk of exposure. A maximum accumulation factor of 5-7 was found in the viscera at both exposure levels. Following the 4-wk exposure period, the fish were transferred to fresh water for a 2 wk depuration period. After 1 wk in fresh water the ^{14}C residue levels decreased by greater than 90% and no detectable ^{14}C residues remained in the fish tissue at the end of the 2 wk period. No effects on the fish were noted during the course of the experiment.

Solomon, K.R., Bowhey, C.S., Liber, K., and G.R. Stephenson. 1988. Persistence of hexazinone velpar triclopyr garlon and 2 4 D in a Northern Ontario Canada aquatic environment. J. Agric. Food. Chem. 36(6):1314-1318.

Stratton, G.W. 1987. The effects of pesticides and heavy metals towards phototrophic microorganisms. In: Reviews in Environmental Toxicology, 3 (Hodgson, E. Ed.). XI+287P. Elsevier Science Publishers B.V.: Amsterdam, Netherlands (Dist. in the USA and Canada by Elsevier Science Publishing Co., Inc.: New York, New York, USA). 0(0):71-148.

Sullivan, D.S., Sullivan, T.P., and T. Bisalputra. 1981. Effects of Roundup herbicide on diatom populations in the aquatic environment of a coastal forest. Bull. Environ. Contam. Toxicol. 26(1):91-96.

The effects of the herbicide Roundup (356 mug/l glyphosate) on algae (diatoms) was studied in 2 streams and 1 pond under 2 different experimental conditions. In the first experiment an experimental area consisting of a small rocky stream leading to a small pond was exposed to Roundup by aerial application at 2.2 kg AI/ha. Sediment samples and glass slides placed in the water were removed immediately prior to spraying and 1, 5, 30 and 47 days after spraying. Diatoms were identified in sediment samples. Photographs were taken of slide samples for identification and counting of genera. Pond sediment samples showed an increase in the Tabellaria in the treated area compared to the controls, and a decline in total diatoms over time. Navicula and Cymbella showed a significantly higher density in the experimental area. Pond slides showed significant changes with time in several of the dominant species. Low density in stream samples precluded their analysis. In a second experiment, one area of the study stream was misted manually with Roundup at field dose (2.2 kg/ha) and another section was misted with 10 times field dose. Each area contained a slide tray containing upright slides; these were analyzed as in the first experiment. Differences in densities of the various genera were

hr. The 96-hr LC50s ranged from 5.8 mg/l for terbutryne to > 30,000 mg/l for dalapon. Safety factors were calculated as the ratio between the 96-hr LC50 and the maximum concentration of herbicide formulation likely to be found in water after use at the recommended level. Paraquat and dichlobenil had the smallest safety factors (13 and 9, respectively). It is concluded that the maximum herbicide concentration likely to be found in water should cause little harm to fish. The possible inhibition of feeding at lower concentrations is suggested.

Tubea, B.I. 1980. The effects of nutrient, pH and herbicide levels on algal growth. Diss. Abstr. Int. B 40(10):4596.

Herbicides enter water systems, whether they are directly applied into water as aquatic herbicides or indirectly drain from cultivated farm lands. Water systems also have different nutrients or pH levels. Experiments were designed to determine the impacts of herbicides, nutrients, or pH levels on algal growth. The growth determinations were made by using stock cultures of Chlorella pyrenoidosa Chick and Lyngbya bergei Dyar. The herbicides used were picloram, prometryne, dinoseb, and fluometuron at 0.1, 1.0 or 10.0 muM. Known combinations of uni-algae cultures, nutrient of pH levels and herbicide concentrations were placed in 50 ml Erlenmeyer flasks. There were no differences in growth rates of algae with the P and K levels used. High levels of Ca and Mg increased growth rates. High levels of N and pH increased the growth of all the algae tested except the pH treatments of *C. pyrenoidosa* when combined with prometryne or fluometuron. Picloram had no effect on growth of any of the algae tested. Dinoseb had an inhibitory effect on *L. bergei*, but no inhibitory effect on *C. pyrenoidosa*. In general, growth inhibition increased as the herbicide concentrations increased, particularly with prometryne and fluometuron. Significant interactions among herbicides and nutrient levels were found for N and pH.

Walker, J.D. 1990. Effects of chemicals on microorganisms. Res. J. Water Pollut. Control Fed. 62(4):618-624.

Walsh, G.E., Weber, D.E., Nguyen, M.T., and L.K. Esry. 1992. Responses of Wetland Plants to Effluents in Water and Sediment. In: Govt Reports Announcements & Index (GRA&I), Issue 07, Environmental Research Lab., Gulf Breeze, FL.

Responses of two wetland vascular plants, Echinochloa crusgalli and Sesbania macrocarpa, exposed to effluents from a coke plant, a pulp mill, a wastewater treatment plant, and the herbicide, hexazinone, were measured in three types of tests: seed germination and early growth, seedling survival and growth in hydroponic culture, and seedling survival and growth in sand and synthetic sediments with clay, silt, and sand, 3, 5, 7.5, or 10% organic contents. There was no effect of effluents or herbicide on germination and survival was affected only by the herbicide. When compared to controls, growth rates were reduced significantly in all tests except for E. crusgalli exposed to effluent from a wastewater treatment plant. There, the effluent stimulated growth in sediments. Increasing concentrations of organic matter in sediments had little effect on toxicity of effluents, but did cause reduced effects of hexazinone. Journal article. Pub. in Environmental and Experimental Botany, v31 n3 p351-358 1991. See also PB91-200337.

The marked comparability, in all six macroinvertebrate biocriteria, exhibited between control and herbicide-treated streams indicated that hexazinone did not adversely impact macroinvertebrates. Fish populations in these streams were low in diversity and abundance, but we found no evidence that hexazinone adversely impacted these communities.

Wedemeyer, G.A., Saunders, R.L., and W.C. Clarke. 1980. Environmental factors affecting smoltification and early marine survival of anadromous salmonids. Mar. Fish. Rev. 42(6):1-14.

A report is presented in which the factors affecting low ocean survivorship of artificially propagated salmon are discussed. Less than 10% of hatchery coho salmon survive, whereas as much as 32% of wild Atlantic salmon survive. Many factors which must be considered when raising fish in a hatchery were reviewed, including physiological changes, hypoosmotic regulatory capability, salinity tolerance and enzyme activity. Environmental parameters that could influence these physiological factors include heavy metals, water temperature, photoperiod, and exposure to pesticides. Exposure of coho salmon smolts to the herbicide Tordon 101 (picloram + 2,4-D) at 0.6-1.8 mg/l for 96 hr prevented successful migration upon release. Low levels of 2,4-D are known to cause an avoidance response in nonanadromous steelhead trout. Recommendations for increasing survivorship are discussed.

Williamson, D.A. 1988. Hexazinone residues in surface and groundwater at two sites within Agassiz Provincial Forest, Manitoba, Canada. Wat. Pollut. Res. J. Can. 23(3):434-449.

Studies were undertaken to determine the fate and effect of <u>Velpar L</u> (<u>hexazinone</u>) on aquatic systems following application to reforestation plantations. Surface water and groundwater were monitored for hexazinone residues. Conventional flask and microplate algal bioassays were conducted using Selanastrum capricornutum Printz, a Microtox bioassay was undertaken using Photobacterium phosphoreum and a S.O.S. chromotest was undertaken using Escherichia coli. Both lateral off-site migration and vertical migration of hexazinone were observed within the surficial aquifer at the study sites. Lateral movement was limited to the extent that less than 10 mug/L were detected in groundwater samples within 5 m of the application site. Hexazinone residues were detected in test wells for a period of approximately 1000 days following application. Hexazinone appeared to move downward in a relatively narrow band at a rate that was artificially enhanced during the process of groundwater sample extraction. Hexazinone residues were detected within ephemeral pools that formed on treated soils for a period of approximately 1000 days following application. <u>Algal bioassay studies indicated inhibition of primary productivity would occur at relatively low hexazinone concentrations (22.5 mug/L).</u> Velpar L was not mutagenic as evidenced by the S.O.S. chromotest and was relatively non-toxic as indicated by the Microtox bioassay.

Willis, G.H., Mcdowell, L.L. 1982. Pesticides in agricultural runoff and their effects on downstream water quality. Environ. Toxicol. Chem. 1(4):267-280.

REFERENCES FOR FOREST HERBICIDES AND WATER QUALITY RESEARCH

Anderson, J.J. and J.J. Dulka. 1985. Environmental fate of sulfometuron methyl in aerobic soils. J. Agric. Food Chem. 33:597-602.

Baur, J.R., R.W. Bovey, and M.G. Merkle. 1972. Concentration of picloram in runoff water. Weed Sci. 20:309-313.

Bouchard, D.C., J.L. Lavy, and E.R. Lawson. 1985. Mobility and persistence of hexazinone in a forested watershed. J. Env. Qual. 14:229-233.

Bovey, R.W., E. Burnett, R.E. Meyer, C. Richardson, and A. Lon. 1978. Persistence of tebuthiuron in surface water runoff water, soil, and vegetation in the Texas Blacklands Prairie. J. Environ. Qual. 7:233-236.

Bush, P.B., D.G. Neary, and J.W. Taylor. 1988. Effect of triclopyr amine and ester formulations on groundwater and surface runoff water quality in the coastal plain. Proc. Southern Weed Science Society. 41:226-232.

Douglass, J.E., D.R. Cochrane, G.W. Bailey, J.I. Teasley, and D.W. Hill. 1969. Low herbicide concentration found in streamflow after a grass cover is killed. Res. Note SE-108. Asheville, NCU. S. Dep. Agric., For. Serv., Southeast. For. Exp. Sta. 3 p.

Edwards, W.M., G.B. Triplett, and R.M. Kamer. 1980. A watershed study of glyphosate transport in runoff. J. Env. Qual. Vol. 9. No. 4: 661-665.

Emmerich, W.E., J.D. Helmer, K.G. Renard, and J.L. Lane. 1984. Fate and effectiveness of tebuthiuron applied to a rangeland watershed. J. Environ. Qual. 13:382-386.

Lavy, T.L., J.D. Mattice, and J.N. Kochenderfer. 1989. Hexazinone persistence and mobility of a steep forested watershed. J. of Environ. Qual. 18:507-514.

Lee, C.H., P.C. Oloffs, and S.Y. Szeto. 1986. Persistence, degradation, and movement of triclopyr and its ethylene glycol butyl ester in a forest soil. J. Agric. Food Chem. 34:1075-1079.

Mayack, D.T., P.B. Bush, D.G. Neary, and J.E. Douglass. 1982. Impact of hexazinone on invertebrates after application to forest watersheds. Arch. Env. Contam. Toxicol. 11:209-217.

Mayeux, H.S., C.W. Richardson, R.W. Dovey, E. Burnett, M.G. Merkle and R.E. Meyer. 1984. Dissipation of picloram in storm runoff. J. Env. Qual. Vol. 13(1)44-49.

McKellar, R.L., O.E. Schubert, B.C. Byrd, L.P. Stevens, and E.J. Norton. 1982. Aerial application of Garlon 3A herbicide to a West Virginia watershed. Down to Earth 38(2)15-19.

Michael, J.L. 1992. Movement and non-target impacts from injection of hexazinone and picloram. U.S. Forest Service Final Report 1.16. (In Press)

Miller, J. H. and A.C. Bace. 1980. Streamwater contamination after aerial application of pelletized herbicide. Res. Note SO-255. New Orleans, LAU. S. Dep. Agric., For. Serv., South. For. Exp. Stn. 4 p.

Neary, D.G., J.E. Douglas and W. Fox. 1979. Low picloram concentrations in streamflow resulting from forest applications of tordon-10k. Proc. South. Weed Sci. 32:182-197.

Neary, D.G. 1983. Monitoring herbicide residues in springflow after an operational application of hexazinone. South. J. Appl. For. 7:217-223.

Neary, D.G., P.B. Bush, and J.E. Douglass. 1983. Offsite movement of hexazinone in streamflow and baseflow from forest watersheds. Weed Sci 31:543-551.

Neary, D.G. 1985. Fate of pesticides in Florida's forests: An overview of potential impacts on water quality. Soil Crop Sci. Soc. Fla. Proc. 44:18-23.

Neary, D.G. 1985. Hydrologic impacts of forest pesticide use. pp. 288-310 In Proceedings of the Southern Forestry Symposium, November 19-21, 1985, Atlanta, Georgia. National Association of Professional Forestry Schools and Colleges, Southern Region. 295 p.

Neary, D.G., P.B. Bush, J.E. Douglass, and R.L. Todd. 1985. Picloram movement in an Appalachian hardwood forest watershed. J. Env. Qual. 14:585-592.

Neary, D.G., P.B. Bush, and J.L. Michael. 1986. Herbicides in southern forestry -- improving water quality. Proceedings of the Southern Weed Science Society 39:335-341.

Neary, D.G., P.B. Bush, and M.A. Grant. 1986. Water quality of ephemeral forest streams after site preparation with the herbicide hexazinone. For. Ecol. Manage. 14:23-40.

Neary, D.G. 1987. Hydrologic impacts of forest pesticide use. In Proceedings Southern Forestry Symposium, November 19-21, 1985, Atlanta, Georgia (S.B. Carpenter ed.). Nat. Assoc. Prof. For. Sch. & Coll., South. Reg. pp. 288-310.

Neary, D.G., P.B. Bush, and J.L. Michael. 1987. Fate of hexazinone and picloram in southern forest watersheds. Proc. Southern Weed Science Society 40:406.

Neary, D.G., P.B. Bush, and J.W. Taylor, Jr. 1987. Triclopyr fate and movement in a coastal plain flatwoods forest ecosystem. Prog. Rep. Gainesville, Florida, S. Dep. Agric., For. Serv., Southeast. For. Exp. Stn. 6 p.

Neary, D.G. 1988. Effects of pesticide applications on forested watersheds. pp. 325-337 In Forest Hydrology and Ecology at Coweeta Ecological Studies 66 (W.T. Swank and D.A. Crossley, eds.), Springer-Verlag, New York, New York. 469 p.

RELATED RESEARCH IN OTHER REGIONS IN THE USA AND CANADA

Feng, J.C., D.G. Thompson, and P.E. Reynolds. 1990. Fate of glyphosate in a Canadian forest watershed aquatic residues and off-target deposit assessment. J. Agric. Food Chem. 38(4)1110-1118.

Newton, M., K.M. Howard, B.R. Kelpsas, R. Danhaus, C.M. Lottman, and S. Dubleman. 1984. Fate of glyphosate in an Oregon forest ecosystem. J. Agric. Food Chem. 32:1144-1151.

Reynolds, P.E. (ed.). 1989. Proceedings of the Carnation Creek Herbicide Workshop. Forest Pest Management Institute, Sault Ste. Marie, Ontario, Canada. 349 pp.

Sidhu, S.S. and J.C. Feng. 1990. Environmental Impacts of Vegetation Management by mechanical and chemical (hexazinone) methods including residue chemistry. Edmonton, Alberta; Forestry Canada. 220 pp.

Smith, A.E., D. Wait, and R. Grover. 1988. Persistence and movement of picloram in a Northern Saskatchewan watershed. J. Environ. Qual. 17:262-268.

Ed Monnig
R-1

Jack's

Issues for Consideration
by the
National Steering Committee
on
Herbicide Use in Vegetation Management
December 1- 2, 1992
Davis, California

Submitted by Edward Monnig

Introduction

I would identify three major areas of consideration for the National Steering Committee on Herbicide Use in Vegetation Management. These three areas are: the socio-political aspects of herbicide use, the environmental/human health impacts of herbicide use, and the efficacy and cost-benefits of various vegetation management techniques. Within these emphasis areas are several high priority needs for consideration.

Socio-political Considerations

The Forest Service is in the vegetation management business; it is a large part of our reason for existing. The vegetation on our landscapes is the clay that we sculpt and canvas on which we work. We manipulate vegetation to produce commodities such as timber, to affect wildlife, to protect rare and endangered species, to enhance water yield or forage, and to ensure public safety. In all these things there is, however, one critical difference between the forester and the sculptor. We are asked to accomplish our tasks while making it look like we have done nothing.

The desire to preserve the natural landscape is salient in the American public and virtually as powerful as its quest for material goods. The Forest Service finds itself searching for some high middle ground in response to these demands. We are in the process of formulating the concepts of ecosystem management as the latest iteration in forest management. In this transition period (some would call it an identity crisis), we are devoting considerable effort to determining how management activities can be reconciled with these concepts. A major challenge for the person in the field is to understand how management activities can be made consistent with these concepts.

One general concept that seems to arise from ecosystem management is that it is less intensive, less focused on single or limited forest outputs. In the absence of a clear understanding of the principles, ecosystem management becomes interpreted as requiring or justifying the discontinuance of traditional techniques associated with intensive management. These include forestry techniques such as clearcutting and the silvicultural use of herbicides. Such techniques now raise a red flag in the minds of many people both inside and outside the agency because of their association with a single product intensive orientation in forest management.

The reluctance to be consider herbicides in silvicultural settings is now fairly pervasive in many parts of the agency. It manifests itself in many

ways. Some examples include the lack of ownership accorded the techniques at the Washington Office staff level. Attempts by the Policy Analysis Group to define responsibilities have apparently been postponed. FPM has often assumed a central role but it seems a role by default rather than by clear mandate.

At other levels in the agency, there is often a reluctance to commit resources for research, planning, and NEPA compliance for herbicide use. This can reflect an assumption of higher priorities in other areas as well as a failure to assume leadership roles by specific staff or field units.

I believe we must recognize that the shift to an ecosystem management approach will foster uncertainty about the role of traditional management techniques. To counter this uncertainty will require a concerted and positive effort. I believe the agency will have to devote considerable resources to several high profile projects that show how more traditional management techniques can be adapted to an ecosystem management approach. Until we have a clearer understanding of the realities of ecosystem management, I believe that the reluctance to invest in traditional techniques such as silvicultural herbicide use will increase.

Environmental and Human Health Concerns

The possible direct environmental and human health effects of pesticide use have been a traditional area of concern. The Forest Service has invested significant time and resources in risk analyses that address both the direct environmental and human health effects of herbicide use. These analyses generally indicate little to no possible adverse effect.

One possible exception is in the area of worker safety. The risk analyses have begun to identify possible concerns with several herbicides whose margins of safety are less than those routinely accepted by the Forest Service. Whether these risks are real or are only an artifact of the conservative nature of these risk analyses is unclear. This uncertainty is affecting the potential use of several herbicides.

Additional field study is needed to determine actual worker doses under representative conditions. At the present time analyses of worker safety are extrapolated from studies conducted under non-representative conditions.

Efficacy Studies

In the past the Forest Service and other organizations have conducted research on the effects of controlling competing vegetation on seedling survival and short term growth. Study plots have been established in many parts of the country. Many of these plots are now approaching 15 to 20 years old and would be appropriately remeasured to determine long-term effects. Unfortunately, support for remeasuring these plots is often unavailable because of a shift in research priorities. This work is somewhat time critical in the Intermountain West. Because of retirements of key personnel, it will become increasingly difficult to recapture the earlier work.

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R-5 Stanislaus NF

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January 22, 1993

USFS Forest Pest Management

National Steering Committee - Vegetation Management
Comments by Michael J. Rutty

The herbicide moratorium of 1984 resulted in reduced planting stock survival (good years frequently showed survival rates of 50% or less), reduced tree growth, plantation failures and on the Stanislaus NF several thousand acres of cutover lands which could not be planted due to the lack of vegetation control.

Many risks were taken to try to keep the planting program from getting too far behind. Some of those risks proved worthwhile, and many were failures.

During this period other solutions were tried and one has proven to provide good site preparation. Deep tilling is accomplished using a dozer with winged tines at a depth of 24"+- inches. First used as a soil compaction mitigation, deep tilling (generally with two passes) can yield two to three years of acceptable brush control even in a species as persistant as bear clover (chamaebatia foliosa). Grass can still be a problem so hand scalping is recommended at time of plant (assuming herbicides are not to be used). This technique has been used on the Eldorado NF as well as the Stanislaus NF for about three years.

In addition to controlling vegetation the tilling reduces soil compaction, facilitates root penetration, and increases water infiltration which in turn reduces erosion and provides more water to on site vegetation (trees). Trees in their second growing season display much greater caliper, larger buds and much longer and darker colored needles than trees on untilled sites.

1991 saw the resurgence of herbicide use in R-5. During that year the Eldorado NF completed their first environmental analysis for plantation release and treated over 2,000 acres.

In 1992 the Stanislaus NF treated approx. 2400 acres of plantations with a second application planned for 1993.

The Eldorado had no local appeals to their projects or demonstrations, which the Stanislaus had four appeals and requests for stays. Responding to the appeals resulted in losing the window for effective grass treatment. The 1993 treatment will be to catch the grass as well as residual brush.

During the applications on the Groveland District, demonstrators in a desparate bid for media attention demonstrated at Crain Flat, the entrance to Yosemite NP. The demonstrators were instructed to leave and they moved down the road a mile or two where there was a Forest Entrance sign. They were several miles from the application site (which was closed by law enforcement personnel).

While not an herbicide application, the Stanislaus also treated 33 rust resistant sugar pines trees with carbaryl as a bark beetle preventive in 1992.

Carbaryl treatments were also applied on the Mendocino and Tahoe NFs.

In the spring of 1992 the Lassen NF applied pronone to 200 acres.

The Sierra also applied herbicides during 1992.

Two other Forests prepared NEPA documents in 1992, the Klamath and the Shasta/Trinity while the Sierra prepared to sign a second document.

On the Stanislaus all four districts are now working on NEPA documents for herbicide use either for site prep, release or both.

On december 18th 1992 the Mi-wok District Ranger signed the first timber sale EA which completely considered all project needs including the use of herbicides for related reforestation activities. This is a first for the Forest as well as for the Region.

The Stanislaus has not yet completed the first environmental impact statements for the 1987 burn. As a group we have pretty much come to the conclusion that these documents are too large. The amount of data involved is difficult to put into an understandable format. The only thing that makes it possible is the use of computers. Subsequent documents are anticipated to be smaller and will probably be EAs.

Chemicals used to date are glyphosate, triclopyr and pronone. There has been no proposals that I know of to use 2,4-D or any other herbicides.

APPENDIX B

United States Department of Agriculture
Forest Service
Washington Office
2121 C Second Street
Davis, CA 95616

Reply To: 2150

Date: December 3, 1992

Subject: Human Exposure Sub-Committee

To: Ed Monnig
R-1/FPM

The National Steering Committee for Managing Vegetation on Forest and Range Lands requests that you chair a sub-committee to review human exposure studies involving herbicides. Specifically your sub-committee to be called "Human Exposure Herbicide Study", would review the literature and produce an annotated bibliography, identify human exposure data gaps, and draft recommendations for committee review. This assignment should be completed by December 1993. Thanks for volunteering to conduct this important study, and please let me know what assistance you might need including coordination with your supervisor.

John W. Barry

JOHN W. BARRY
Chairperson

cc: Committee Members
Bill Boettcher
Doug Parker
Jesus Cota
Zdenka Horakova
Jim Space

APPENDIX C

United States Department of Agriculture | Forest Service | Washington Office | 2121 C Second Street
Davis, CA 95616

Reply To: 2150

Date: December 4, 1992

Dr. Bob Campbell
Forest Pest Management Institute
P.O. Box 490
Sault Ste. Marie, Ontario, Canada
P6A 5M7

Dear Bob:

Thanks for making the long trek south to participate in the 3rd meeting of the National Steering Committee for Managing Vegetation on Forest and Range Lands. I believe we had a highly productive meeting because of the active participation by attendees and their high level of enthusiasm.

The committee appreciates your willingness to chair the new sub-committee "Vegetation Management Monitoring Database." The sub-committee should address the need for a database of environmental and efficacy data generated by herbicide projects. Operational and other projects provide opportunities to capture and archive data that are useful for a number of purposes including modeling. For data to be meaningful, therefore, its generation, collection, and storage needs a protocol and consistency. Therefore the initial charge of your sub-committee is to outline an approach to establishing a database that includes criterion to be followed and to be reported by project people who are willing to participate.

The committee realizes that this is an ambitious challenge and we appreciate your interest in accepting the task. Please let me know if you need assistance in identifying potential sub-committee members. We look forward to your reporting at the 1993 meeting of the steering committee.

Sincerely,

Jack

JOHN W. BARRY
Chairperson

cc: Committee Members
Jesus Cota
Zdenka Horakova
Nancy Lorimer
Jim Space

APPENDIX D